WELDING SYSTEM

USER'S MANUAL

CWS-D100-1B

CWS-D100-2B

Swagelok®

The Swagelok Limited Lifetime Warranty

Swagelok hereby warrants to the purchaser of this Product that the non-electrical components of the Product shall be free from defects in material and workmanship for the life of the Product. All electrical components installed in or on the Product are warranted to be free from defects in material and workmanship for twelve months from the date of purchase.

The purchaser's remedies shall be limited to replacement and installation of any parts that fail through a defect in material or workmanship.

MANUFACTURER SPECIFICALLY DISAVOWS ANY OTHER REPRESENTATION, EXPRESS OR IMPLIED, WARRANTY, OR LIABILITY RELATING TO THE CONDITION OF USE OF THE PRODUCT, AND IN NO EVENT SHALL SWAGELOK BE LIABLE TO PURCHASER, OR ANY THIRD PARTY, FOR ANY DIRECT OR INDIRECT CONSEQUENTIAL OR INCIDENTAL DAMAGES.

Table of Contents

Section 3 Operation

Foreword

Registration Information

Your Swagelok® representative can provide support and service of your Swagelok Welding System (SWS) as well as local stock of precision fittings and valves.

Please take a moment to fill out the warranty information form as well as the information listed below. Keep this information available in case you need to contact your Swagelok representative.

Power Supply:

Model Number*: _____

Serial Number*: _____

Delivery Date: _____

* See rating label on the rear of the unit, shown in Figure 1.

Weld Head(s):

Weld Head:

Model Number: _____

Serial Number: _____

Delivery Date: _____

Model Number: _____

Serial Number: _____

Delivery Date: _____

Model Number: _____

Serial Number: _____

Delivery Date: _____

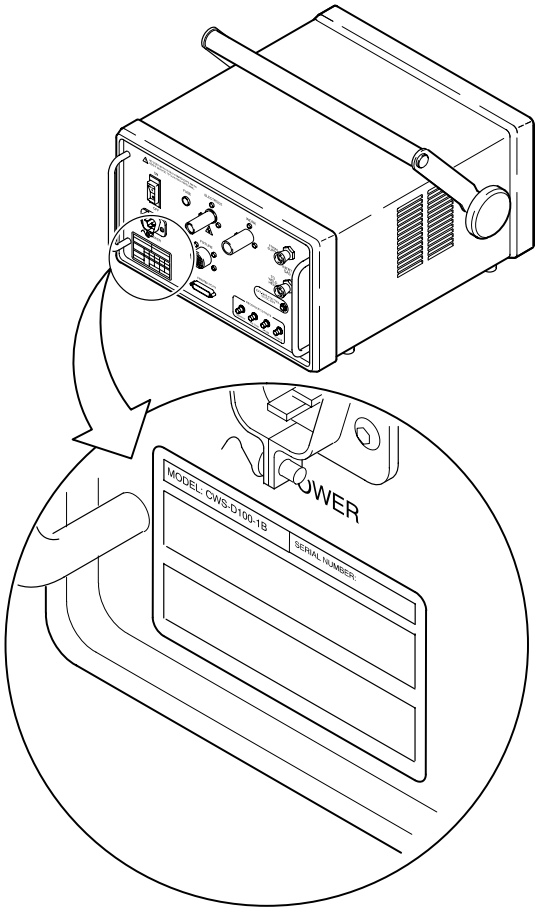


Figure 1 Rating Label

Safety Summary

The safety information presented here pertains to both the Swagelok® Welding System (SWS) and the process of Gas Tungsten Arc Welding (GTAW).

Read Operating Instructions

Read all of the instructions in this manual prior to operating the SWS.

Statements

Caution! Statements identify conditions or practices that could result in damage to the equipment or other property.

WARNING! Statements identify conditions or practices that could result in personal injuries or loss of life.

Symbols

The following symbols are used in this manual and on the equipment to visually identify where warning or caution information is found. Consult symbols and related instructions below for necessary actions to avoid the hazards.

WARNING or Caution

This symbol identifies the location of all other types of warning or caution information which don't have specific symbols. Accompanying text will identify the specific nature of the condition and if the condition is a warning or caution.

ELECTRIC SHOCK can kill.

Touching live electrical parts can cause fatal shocks and severe burns. Incorrectly installed or improperly grounded equipment is a hazard.

- Do not touch live electrical parts
- No user serviceable parts in the power supply other than a fuse. Refer all other power supply servicing to your Authorized Swagelok representative.
- Keep all panels and covers securely in place. Do not touch electrode connector, electrode, or rotor after pressing start. The electrode is live during the weld cycle.
- Verify that the power supply is properly grounded before use. Make sure the power cord is plugged into a properly wired and grounded receptacle.
- Follow local electrical codes and the guidelines in the manual when installing the SWS. Failure to do so may create an electrical shock hazard. Shock hazards can exist even when equipment is properly installed, so it is important that the operator be trained in the proper use of the equipment and follow established safety practices.
- Frequently inspect input power cord for damage or bare wiring – replace immediately if damaged.
- Properly unplug the power cord. Grasp the plug to remove it from the receptacle.
- Do not use extension cords that are in poor physical condition or have insufficient current capacity. Failure to do so can pose fire and shock hazards.

FUMES AND GASES can be hazardous.

Welding produces fumes and gases. Breathing these fumes and gases can be hazardous to your health. Build−up of gases can displace oxygen and cause injury or death.

- Do not breathe fumes or gases.
- If inside, ventilate the area and/or use exhaust at the arc to remove welding fumes and gases.
- If ventilation is poor, use an approved air-supplied respirator.
- Read the Material Safety Data Sheets (MSDSs) and the manufacturer's instructions for metals, consumables, coatings, cleaners, and degreasers.
- Work in a confined space only if it is well ventilated or while wearing an air−supplied respirator. Always have a trained watch−person nearby. Welding fumes and gases can displace air and lower the oxygen level causing injury or death. Be sure the breathing air is safe.
- Do not weld in locations near degreasing, cleaning, or spraying operations. The heat and rays of the arc can react with vapors to form highly toxic and irritating gases.
- Do not weld on coated metals, such as galvanized, lead, or cadmium plated steel, unless the coating is removed from the weld area, the area is well ventilated, and if necessary, while wearing an air−supplied respirator. The coatings and any metals containing these elements can give off toxic fumes if welded.
- The ultraviolet light emitted by the welding arc acts on the oxygen in the surrounding atmosphere to produce ozone. Test results[1] , based upon present sampling methods, indicate the average concentration of ozone generated in GTAW process does not constitute a hazard under conditions of good ventilation and welding practice.

  1 WELDING HANDBOOK, VOLUME 2, 8TH EDITION, AMERICAN WELDING SOCIETY.

- Shut off shielding gas supply when not in use.

ARC RAYS can burn eyes.
NOISE can damage hearing.

Arc rays from the welding process produce intense visible and invisible (ultraviolet and infrared) rays that can burn eyes. The SWS is meant for use only with enclosed weld heads which minimize exposure to these harmful rays.

- Do not look at welding arc.
- Use protective screens or barriers to protect others from flash and glare; warn others not to watch the arc.
- Wear approved ear protection if noise level is high.

WELDING can cause fire or explosion.

Welding on closed containers, such as tanks, drums, or pipes, can cause them to blow up. The hot work piece and hot equipment can cause fires and burns. Check and be sure the area is safe before doing any welding.

- Protect yourself and others from the hot work piece.
- Watch for fire, and keep a fire extinguisher nearby.
- Do not weld on closed containers such as tanks, drums, or pipes, unless they are properly prepared according to AWS F4.1.
- Do not use welder to thaw frozen pipes.
- Do not use extension cords that are in poor physical condition or have insufficient current capacity. Failure to do so can pose fire and shock hazards.

Safe Practices and Safety Precautions

READ ANSI Z49.1

Safety and safe practices in welding, cutting and allied processes are covered in ANSI Z49.1, *SAFETY IN WELDING AND CUTTING*. When using the SWS, follow all basic safety practices.

CYLINDERS can explode if damaged.

Shielding gas cylinders contain gas under high pressure. If damaged, a cylinder can explode. Since gas cylinders are normally part of the welding process, be sure to treat them carefully.

WARNING!

SHIELDING GAS CYLINDERS CAN EXPLODE IF DAMAGED OR IMPROPERLY TREATED.

- Protect compressed gas cylinders from excessive heat, mechanical shocks, slag, open flames, sparks, and arcs.
- Install cylinders in an upright position by securing to a stationary support or cylinder rack to prevent falling or tipping.
- Keep cylinders away from any welding or other electrical circuits.
- Never weld on a pressurized cylinder − explosion will result.
- Use only correct shielding gas cylinders, regulators, hoses, and fittings designed for the specific application; maintain them and associated parts in good condition.
- Turn face away from valve outlet when opening cylinder valve.
- Keep protective cap in place over valve except when cylinder is in use or connected for use.
- Read and follow instructions on compressed gas cylinders, associated equipment, and CGA publication P−1 listed in *Safety Standards*.

WARNING!

SHIELDING GAS CYLINDERS CAN EXPLODE IF DAMAGED OR IMPROPERLY TREATED.

HOT PARTS can cause severe burns.

After welding, the work piece, weld head, and electrode can be extremely hot and may cause burns.

WARNING!

PACEMAKER WEARERS KEEP AWAY.

MAGNETIC FIELDS can affect pacemakers.

- Pacemaker wearers keep away.
- Wearers should consult their doctor before going near welding operations.

User Precautions

- **Power Supply Grounding**

  The power supply is grounded through the ground connector of the power cord. Avoid electrical shock by making sure the power cord is plugged into a properly wired and grounded receptacle before turning the unit on.

WARNING!

VERIFY THAT THE SYSTEM IS PROPERLY GROUNDED BEFORE USE.

- **Water and Moisture**

  System components are not waterproof. Do not expose the SWS equipment to water.

- **Proper Use and Storage**

  Do not store or use near hazardous materials. Store indoors and cover the system when not in use.

- **Weld Heads**

  Disconnect the weld head completely from the power supply prior to servicing.

  User service, including cleaning or component replacement, is limited to those operations identified in this manual.

- **Fixture Blocks**

  Disconnect the fixture block from the weld head prior to servicing. User service, including cleaning or component replacement, is limited to those operations identified in this manual.

- **Power Supply Service**

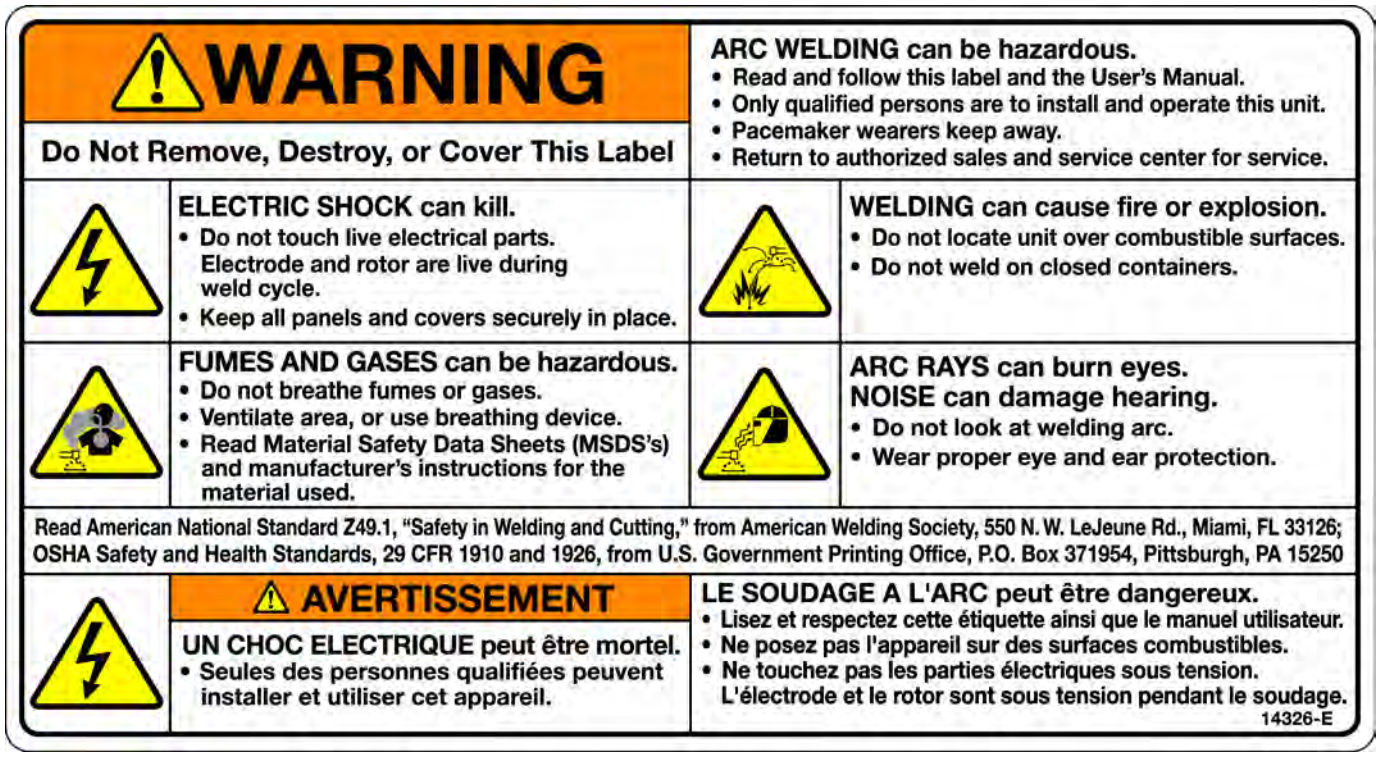
  There are no user serviceable parts in the power supply other than a fuse. Refer all other servicing to your Authorized Swagelok sales and service representative.

WARNING!

USERS SHOULD NOT SERVICE THE POWER SUPPLY.

Power Supply Warning Label

This warning label is affixed to the power supply.



Referenced Specifications

1. AWS F4.1, *Recommended Safe Practices for the Preparation for Welding and Cutting of Containers and Piping.*

   American Welding Society, 550 N.W. LeJeune Rd, Miami, FL 33126 (www.aws.org).

2. ANSI Z49.1, *Safety in Welding Cutting, and Allied Processes.*

   American Welding Society, 550 N.W. LeJeune Rd, Miami, FL 33126 (www.aws.org).

3. CGA Publication P−1, *Safe Handling of Compressed Gases in Cylinders.*

   Compressed Gas Association, 4221 Walney Road, 5th Floor, Chantilly VA 20151−2923, (www.cganet.com).

4. OSHA 29CFR 1910 Subpart Q, *Welding Cutting, and Brazing.*

   Acquire from U.S. Government Printing Office, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250 (www.osha.gov).

5. OSHA 29CFR 1926 Subpart J, *Welding and Cutting.*

   Acquire from U.S. Government Printing Office, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250 (www.osha.gov).

Section 1
Introduction
SWS D100

The Swagelok Welding System (SWS) is a versatile, portable and easy to use orbital welding system. This section includes

- gas tungsten arc welding
- system components
- overview of SWS operation
- specifications.

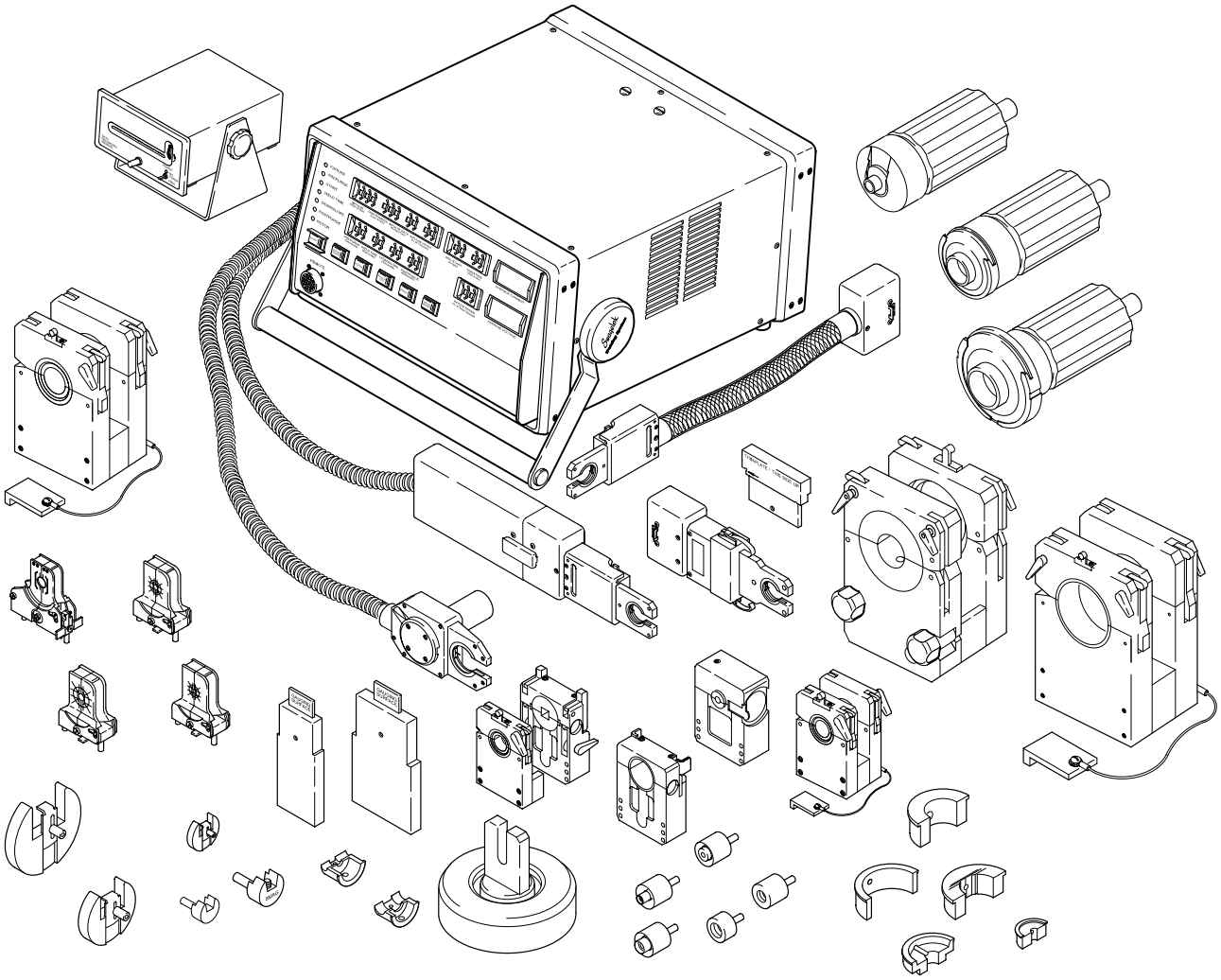


Figure 1-1 Swagelok Welding System

The purpose of this manual is to familiarize you with the SWS and to provide the reference information needed to produce high-quality, repeatable welds.

While reading, you may encounter unfamiliar terminology. Some terms are common to the welding industry and others particular to the SWS. Refer to Appendix A, *Glossary,* if necessary.

Gas Tungsten Arc Welding

Principles of the GTAW Process

Gas Tungsten Arc Welding (GTAW) is a welding process that creates an arc between a nonconsumable tungsten (or tungsten alloy) electrode and the work. The electrode is held in a torch, rotor, or other device. GTAW uses a shielding gas, most commonly Argon, that is delivered to the weld area. The shielding gas envelops the weld joint and electrode, protecting both from contamination by the atmosphere.

The electric arc which creates the weld is produced by the passage of current through the conductive ionized shielding gas. The arc is established between the tip of the electrode and the work. Heat generated by the arc melts the base metal. Once the arc and weld puddle are established, the electrode moves along the joint and the arc progressively melts the joint surface. Filler wire, if used, is added to the leading edge of the weld puddle to fill the joint.

GTAW provides precise control of heat input to the weld joint. For this reason, it is preferred for joining thin gage metals and for making welds close to heat sensitive components. The process offers advantages to many industries, ranging from the high purity required in the semiconductor industry to autogenous manual welds of the process industry.

The process can be used to weld almost all metals. GTAW can be used to weld all types of joint geometries in tubing, pipe, or other structural shapes. It is particularly appropriate for welding wall sections less than 3/8 in. (9,5 mm) thick.

GTAW Process Advantages

The GTAW process has the following advantages:

- produces superior quality welds
- allows excellent control of weld penetration
- welds almost all metals
- produces autogenous welds at high speeds
- allows precise control of the welding variables
- welds with or without filler metal
- eliminates spatter

Process Variables

The major process variables in GTAW are arc current, arc voltage, and travel speed.

- **Arc Current** − The current measured between the tungsten electrode and the work.

  Generally stated, arc current controls the weld penetration.

  Direct Current Electrode Negative (DCEN) is common for GTAW. It offers the advantages of deep penetration and fast welding speeds because most of the heat generated in the welding process is transferred to the work.

- **Arc Voltage** − The voltage measured between the tungsten electrode and the work.

  Arc voltage is affected by the following:

  - arc current
  - shape of the tungsten electrode tip
  - type and purity of shielding gas
  - arc length (distance between the electrode and the work)

  Arc length is important with this process because it affects the width of the weld puddle; puddle width is proportional to arc length. The desired arc length is as short as possible.

- **Travel Speed** − The speed that the electrode moves over the work while welding.

  Travel speed affects both the width and weld penetration of GTAW. Its effect on width is more pronounced than on penetration. Increasing travel speed decreases the width of the weld.

  Travel speed generally is fixed in mechanized welding. Other variables such as current or voltage are varied to maintain control of the weld.

System Components

The SWS D100 Power Supply

The power supply features microcontroller electronics and closed-loop circuitry to precisely control output current. Simplified controls and displays provide efficient programming and monitoring of the welding process.

See Table 1-1 on page 1-9 for the power supply specifications.

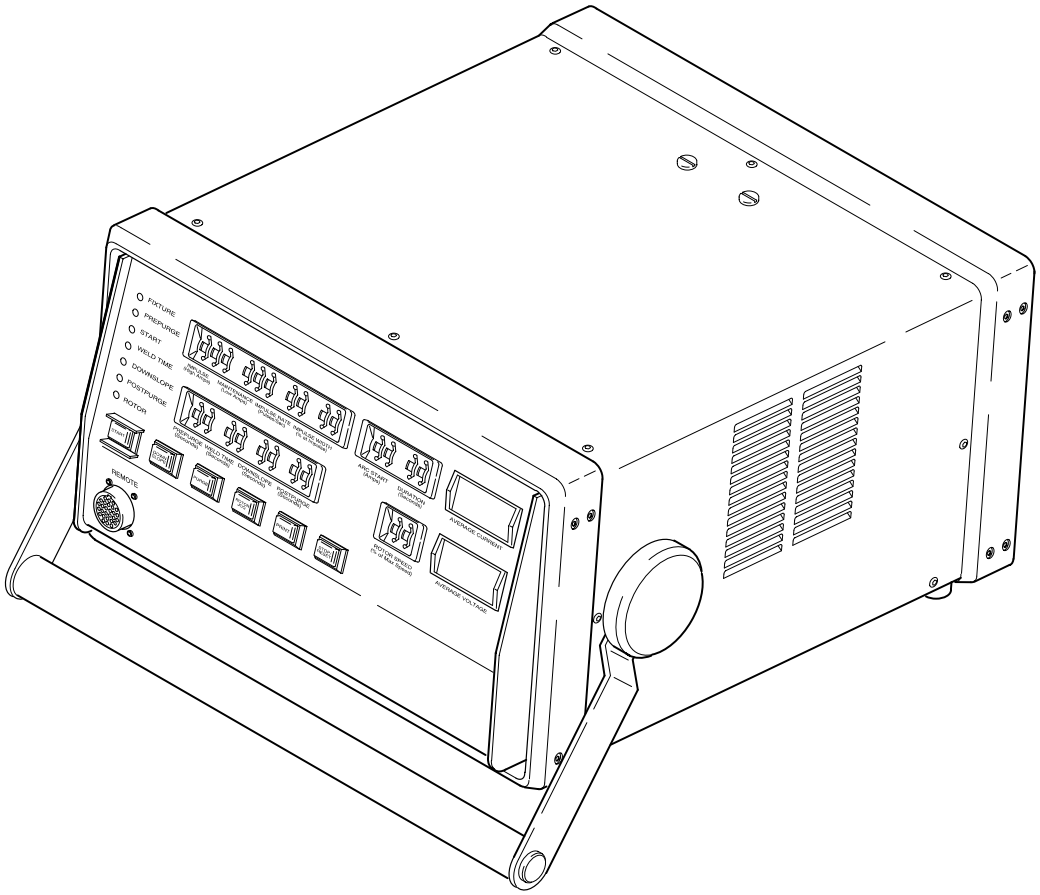


Figure 1-2 SWS D100 Power Supply

The Weld Head

The SWS weld heads deliver consistent, precise welds for outside diameters from 1/16 in. to 2 in. (3 mm to 52 mm). There are six weld heads to choose from, depending on the size of the work pieces. See Figure 1-3.

A dc motor in the weld head drives a rotor which carries the tungsten electrode around the weld joint. Optical circuitry in the weld head sends precise feedback to the power supply to control the speed of the rotor.

All moving parts in the weld head mount in low-friction devices to provide smooth, consistent operation.

A spring-loaded, floating brush continuously contacts approximately one-third of the circumference of the rotor at all times. This configuration ensures consistent, uniform electrical conductance to the rotor and electrode.

See Table 1-5 on page 1-10 for the weld head specifications.

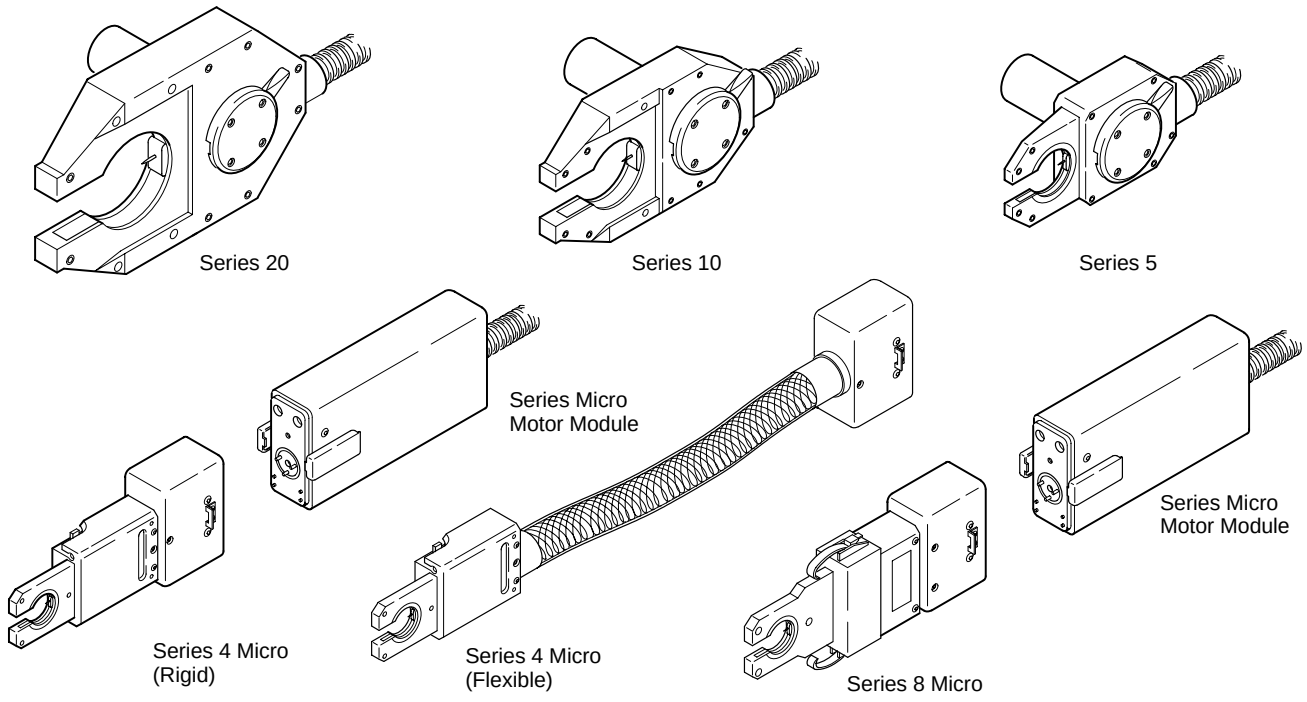


Figure 1-3 Weld Heads

Fixture Blocks

The SWS fixture blocks accurately align and hold tubing, fittings, and valve bodies. The modular design allows you to select different side plates and create the configuration needed for the job.

The fixture block is separate from the weld head, allowing work pieces to be easily aligned and fixtured before welding. The use of multiple fixture blocks offers increased productivity.

Each fixture block is designed to accommodate a range of work piece sizes. A unique and patented Universal Collet Insert (UCI) fits into the fixture block to match the diameter of the work piece. The collet design firmly holds tubing and fittings that vary ± 0.005 in. (0,13 mm) from nominal outside diameter. Collets are also available for thin wall pipe. The collets exchange quickly, making the fixture block very adaptable to changing work requirements. Tables 1-6, 1-7, and 1-8 list the available fixtures and collets.

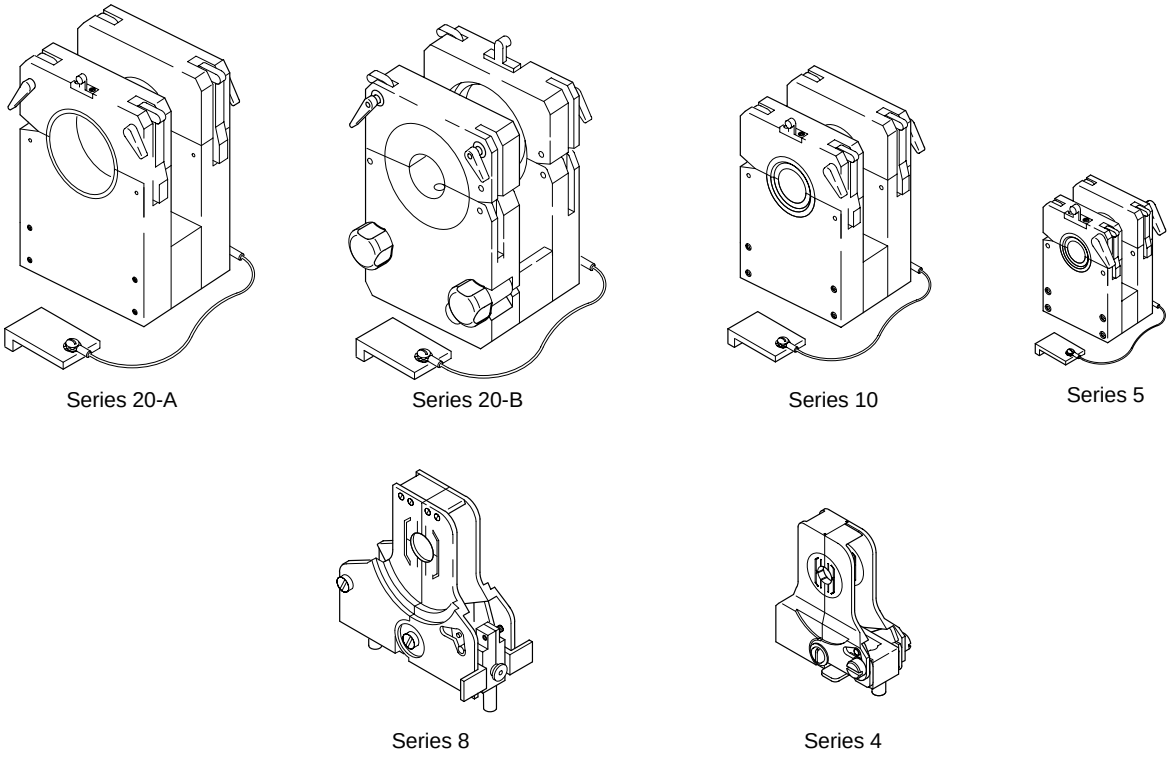


Figure 1-4 Standard Fixtures

Overview of SWS Operation

GTAW Orbital welding is a proven method for welding cylindrical shapes such as tubes, fittings, and pipe. The SWS design makes the orbital welding process efficient and effective.

The SWS provides an advanced method of autogenous GTAW. The system uses a fixture block and associated weld head to provide precise fixturing of the work pieces. The welding parameters are controlled by the SWS power supply and are programmed by the operator.

Operating the SWS is uncomplicated. The work piece sizes define the fixture block configuration, collets, and weld head to be used.

The fixture block quickly clamps onto the work pieces. The weld joint is centered in the fixture block using a centering gage. Since the fixture block is not part of the weld head, multiple fixture blocks can be used to maximize weld setup efficiency.

The weld head cable assembly attaches quickly to the power supply. Setup of the weld head is limited to the selection of an electrode and setting the arc gap. The arc gap setting depends on the characteristics of the work pieces. A gage is provided with the weld head to assist in setting the arc gap. After the arc gap is set, the weld head attaches to the fixture block and is secured with a locking ring.

The power supply uses rotary switches for weld parameter control. See Figure 1-5. The appropriate switch settings are generally defined by the work pieces to be welded and are refined using test welds. The correct settings used for a specific job are developed into a weld procedure guideline. The guideline is used to maintain repeatability and quality control for subsequent jobs of the same type.

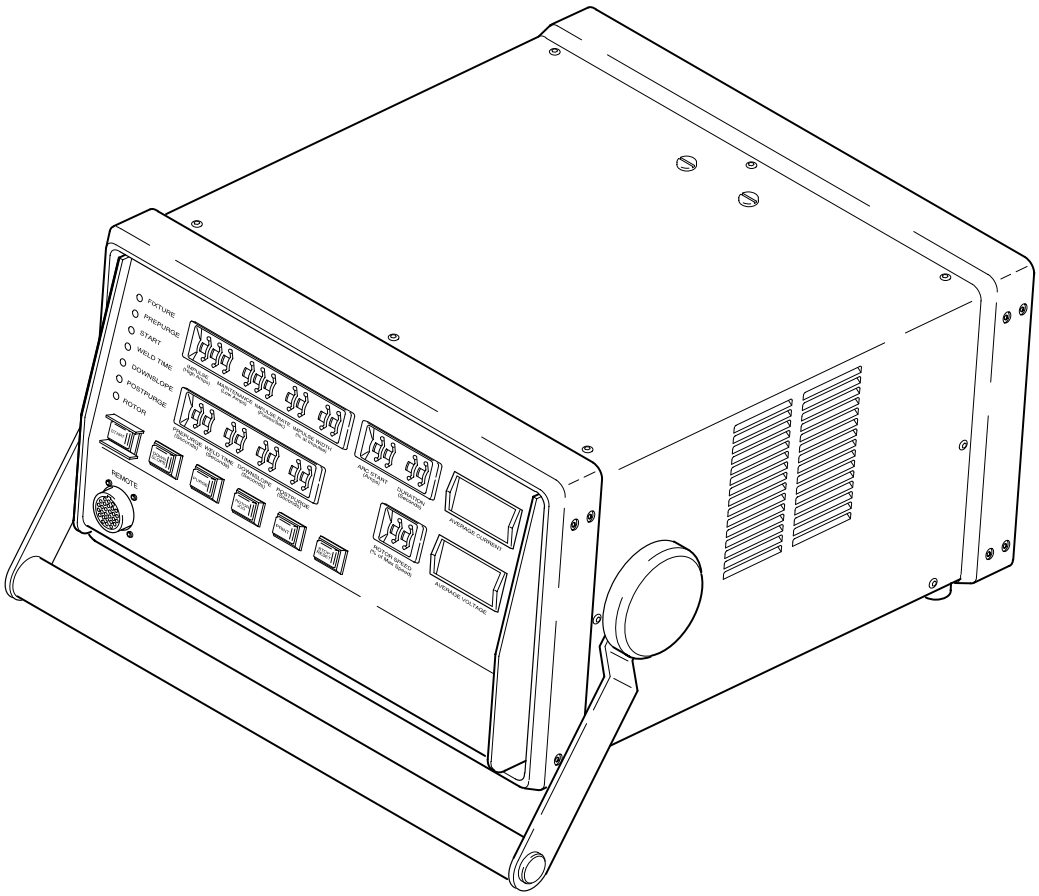


Figure 1-5 SWS D100 Front Panel Controls

Specifications

Table 1-1 Power Supply

Model	Supply Voltage*	Service Amps	Output Current (dc)
CWS-D100-1B	115 V (ac)	20 A	2 to 100 A
CWS-D100-1B	115 V (ac)	15 A	2 to 70 A
CWS-D100-2B	230 V (ac)	15 A	2 to 100 A

* 10% input voltage tolerance, frequency range 50 Hz to 60 Hz

Table 1-2 Duty Cycle

Model	6.25 %	60 %	100 %
CWS-D100-1B	100 Amps 14 Volts	32.3 Amps 11.3 Volts	25 Amps 11 Volts
CWS-D100-2B	100 Amps 14 Volts	32.3 Amps 11.3 Volts	25 Amps 11 Volts

Duty cycle is the ratio of time the power supply can weld to the time the power supply must remain idle to cool. The 10 minute cycle is a recognized welding industry standard. It represents the maximum weld time allowed, with the balance of the 10 minute cycle required for cooling.

Table 1-3 10 Minute Cycle Times

Duty Cycle Rating	Maximum Weld TIme (Minutes)	Required Idle Time (Minutes)
30 %	3	7
60 %	6	4
100 %	10	0

Continually exceeding the duty cycle may activate an internal thermal protector that will disable the power supply and display message code 50. Refer to pages 3-13 and 3-15.

Table 1-4 Power Supply Dimensions and Weight

Model	Dimensions (overall)	Weight
CWS-D100-1B	15 1/2 in. (39 cm) wide 20 in. (51 cm) deep 9 in. (23 cm) high (without handle)	42 lbs (19 kg)
CWS-D100-2B	15 1/2 in. (39 cm) wide 20 in. (51 cm) deep 9 in. (23 cm) high (without handle)	45 lbs (20.4 kg)

Table 1-5 Weld Heads

Series	Model	OD Capacity
4 Micro*	CWS-4MRH-A CWS-4MFH-A	1/16 to 1/4 in. (3 to 6 mm)
8 Micro*	CWS-8MRH	1/4 to 1/2 in. (6 to 12 mm)
5	CWS-5H-B	1/8 to 5/8 in. (3 to 16 mm)
10	CWS-10H-A	1/4 to 1 in. (6 to 25 mm)
20	SWS-20H-B**	1/2 to 2 in. (12 to 52 mm)

* Requires CWS-M-MTR-A motor module

** Requires SWS-20TFB-A

Table 1-6 Standard Fixture Blocks

Model	OD Capacity	Minimum Weld Extension Length
CWS-4MFA-**	1/16 to 1/4 in. (3 to 6 mm)	1/4 in. (6 mm)
SWS-8MFA-**	1/4 to 1/2 in. (6 to 12 mm)	1/4 in. (6 mm)
CWS-5TFB	1/8 to 5/8 in. (3 to 16 mm)	3/4 in. (19 mm)
CWS-10TFB	1/4 to 1 in. (6 to 25 mm)	3/4 in. (19 mm) (recessed) 15/16 in. (24 mm) (no recess)
CWS-20TFB	1/2 to 2 in. (12 to 52 mm)	1 3/8 in. (35 mm)
SWS-20TFB-A	1/2 to 2 in. (12 to 52 mm)	1.45 in. (37 mm)

** Designates size in 1/16ths or mm; 4MFA- includes sizes 01, 02, 04, 3 mm, and 6 mm. 8MF- includes sizes 04, 06, 08, 6 mm, 8 mm, 10 mm, and 12 mm

Table 1-7 Special Purpose Fixture Side Plates

Model	Used for	Comments
CWS-5FSP1	VCR®, S Type VCR, VCO®, B Type VCO fittings, and tubing	weld extension length must be less than 0.75 in. (19 mm) requires adapter inserts
CWS-5FSP2	Micro-Fit® fittings and tubing	requires Micro-Fit fitting collets
CWS-5HBDA-BW4 CWS-5HBDA-BW6 CWS-5HBDA-BW6MM	BN, DL, DS, HD, HB, DA* style valve bodies	1/4 in., 3/8 in., or 6 mm tubular weld fittings and tubing butt weld ends
SWS-20FSP1L	tubular weld fittings and tubing	0.80 in. (20 mm) weld extension length requires SWS-20UCI-XXTN collets
SWS-20FSP1R	tubular weld fittings and tubing	0.80 in. (20 mm) weld extension length requires SWS-20UCI-XXTN collets

* DA − manual actuator only

Table 1-8 Collets

Model	OD Capacity	Comments
CWS-5UCI-**	1/8 in. to 5/8 in. (3 mm to 16 mm)	tubing add “mm” suffix for metric sizes.
CWS-5UFCI-.95	n/a	fixture collets to hold adapter inserts for CWS-5FSP1 side plate
CWS-5UFCI-**	1/8 in. to 5/8 in. (3 mm to 16 mm)	tube collet for special purpose side plates
CWS-5MWCI-04	1/8 in., 1/4 in., 6 mm	for Micro-Fit fittings
CWS-5MWCI-06	3/8 in., 8 mm, 10 mm	for Micro-Fit fittings
CWS-5MWCI-08	1/2 in., 12 mm	for Micro-Fit fittings
CWS-10UCI-**	1/4 in. to 1 in. (6 mm to 25 mm)	tubing
CWS-20UCI-**	1/2 in. to 2 in. (12 mm to 52 mm)	tubing
CWS-20UCI-**P	1/4 in. to 1 1/2 in. (10.2 mm to 48.3 mm)	pipe add J suffix for JIS pipe (-**PJ) add MMP suffix for metric pipe (-**MMP)
SWS-20UCI-**TN	1/2 in. to 2 in. (12 mm to 52 mm)	tubular weld fitting collet for SWS-20FSP1L and SWS-20FSP1R add MM (MMTN) suffix for metric sizes
SWS-20UCI-MC	n/a	collet to hold ferrule mandrels for SWS-20TFB-A fixture block

** − Identifies the collet size in 1/16ths or metric (MM suffix)

Table 1-9 Adapter Inserts for CWS-5FSP1

Model	Used for	Comments
CWS-5MBVCO-04	316L-4-BVCO-1 316L-4-VCO-1-4TB2 1/4 in. VCR weld glands	glands must have overall length of 1.12 in. (28 mm) or less with captured male nut SS-4-SVCR-4
CWS-5FVCR-04	1/4 in. VCR weld glands	glands must have overall length of 0.72 in. (18 mm) or less with captured female nut SS-4-VCR-1
CWS-5FBVCO-04	316L-4-BVCO-3 1/4 in. VCR weld glands	glands must have overall length of 0.77 in. (20 mm) or less with captured female nut SS-4-VCR-1
CWS-5MSVCR-04	6LV-4-SVCR-3	with captured male nut SS-4-SVCR-4
CWS-5FSVCR-04	6LV-4-SVCR-3S 6LV-4-SVCR-3	with captured female nut SS-4-SVCR-1

WARNING!

DO NOT USE EXTENSION CORDS THAT ARE IN POOR PHYSICAL CONDITION OR HAVE INSUFFICIENT CURRENT CAPACITY. FAILURE TO DO SO CAN POSE FIRE AND SHOCK HAZARDS.

Table 1-10 Extension Cords

Model	Supply Voltage	Wire gauge 0 ft to 50 ft (0 m to 15 m)	Wire gauge 50 ft to 100 ft (15 m to 30 m)
CWS-D100-1B	115 V (ac)	#12 AWG (2,5 mm)	#10 AWG (4,0 mm)
CWS-D100-2B	230 V (ac)	#12 AWG (2,5 mm)	#10 AWG (4,0 mm)

Some power loss will occur, depending on the length of the extension cord. See Table 1-10 to determine the **minimum** wire size to use.

Section 2
Installation

Introduction

This section describes the procedures necessary for installing the Swagelok Welding System (SWS). This section includes:

- tools and accessory requirements
- electrical requirements
- unpacking and inspecting system components
- installing the SWS
- installing the gas delivery system
- preliminary check.

Tools and Accessory Requirements

You need the following tools and accessories to install and operate your SWS.

Tool/Accessory	Included?	Provided With
Hex Wrenches (0.050 in. to 5/32 in.)	Yes	Weld Head
Electrode Package	Yes	Weld Head
Arc Gap Gage	Yes	Weld Head
Flat Blade Screw Driver	Yes	Weld Head
Centering Gage	Yes	Fixture Block
Quick−Connect® Stem	Yes	Power Supply
Secondary Solenoid Bypass Plug	Yes	Power Supply
Dial/Digital Calipers or Micrometer	No	−
Purge Connector(s)	No	−
Shielding/Purge gas lines(1)	No	−
Shielding/Purge Gas Source(2)	No	−
Pressure Regulator(3)	No	−
Internal Purge Gas Flow Meter	No	−
Shielding Gas Flow Meter	No	−

(1) All lines used for shielding/purge gas should be the low moisture absorption type.

(2) A compressed gas bottle or liquid Dewar source can be used. Argon is the gas most frequently used.

(3) A two-stage gas regulator is suggested. The regulator should reduce the source pressure to 25 psig to 50 psig (1.9 bar to 3.5 bar) for the arc shielding and internal (backing) purge flow meters.

Electrical Requirements

Input Voltage

Table 2-1 lists the electrical requirements for the power supply.

Table 2-1 Power Supply Electrical Requirements

Power Supply Model	Voltage Requirement	Service Current
CWS-D100-1B	115 V* (ac)	20 A
CWS-D100-2B	230 V (ac)	15 A

* If the input voltage is 100 V or less, the output power capabilities may be reduced.

Ensure that the following guidelines are adhered to when considering the electrical requirements for the power supply:

- All wiring and related components must be installed according to local and National Electrical Codes.
- The power supply must be grounded.
- A dedicated electrical circuit must be used.

WARNING!

THE POWER SUPPLY MUST BE GROUNDED. IF IT IS NOT GROUNDED, ELECTRIC SHOCK CAN OCCUR.

Using an Extension Cord

If it is necessary to use an extension cord, follow these guidelines:

- The wire size must meet the specifications indicated in Table 1-10, located in Section 1, *Introduction*.
- If the length of the cord is greater than 100 ft, call your Swagelok representative for recommended guidelines.

Note: *The voltage drop in an extension cord 100 ft long may affect the output performance of the SWS.*

Unpacking and Inspecting System Components

Unpacking the Power Supply

The SWS power supply is packaged in a wooden shipping container. See Figure 2-1. The power supply part number and serial number are located on a label on the outside of the container.

Note: *Keep the shipping container and the foam inserts for storing and/or shipping.*

Table 2-2 lists the contents of the shipping container.

Table 2-2 Shipping Container Contents

Part Description	Part No.	Qty.
Welder Power Supply	CWS-D100-*B	1
Power Cord	CWS-CORD-*	1
1/4 in. Male QC	SS-QC4-S-400	1
Secondary Solenoid Bypass Plug	–	1
Swagelok Welding System User's Manual	CWS-MANUAL-D100B-**	1

* Denotes Model ** Denotes Language

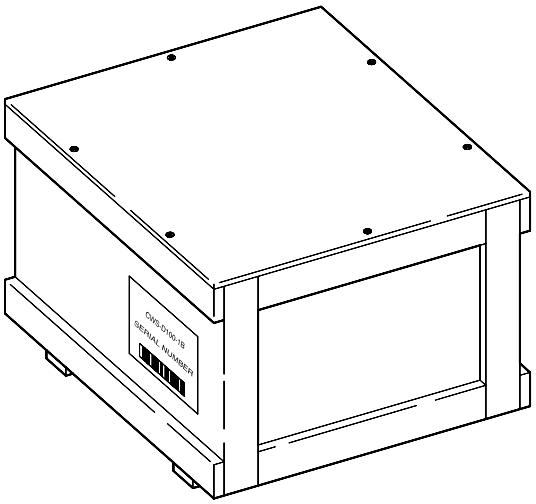


Figure 2-1 Shipping Container

Remove the contents of the shipping container by performing the following steps:

1. Remove the following items:
   - Swagelok Welding System User's Manual
   - Swagelok Quick-Connect stem
   - secondary solenoid bypass plug
   - power cord
2. Remove the power supply by lifting it by the handle. Remove the side foam inserts. Place the power supply on a stable cart, platform, or table.
3. Check the power supply and accessories for damage.
4. Check that the serial number on the rear panel of the power supply matches the serial number on the shipping container label.
5. Record the model and serial numbers, and the delivery dates on page i of the *Forward* section of this user's manual.

Unpacking the Weld Head Cable Assembly and Related Components

The following weld head components are packaged in a foam-lined shipping container:

- weld head assembly
- arc gap gage
- electrode package
- tool package

1. Inspect the container for damage.
2. Remove the components from the container.
3. Check the items for any damage.
4. Verify that the weld head serial number matches the serial number on the shipping container.
5. Record the model and serial numbers, and the delivery dates on page i of the *Forward* section of this user's manual.

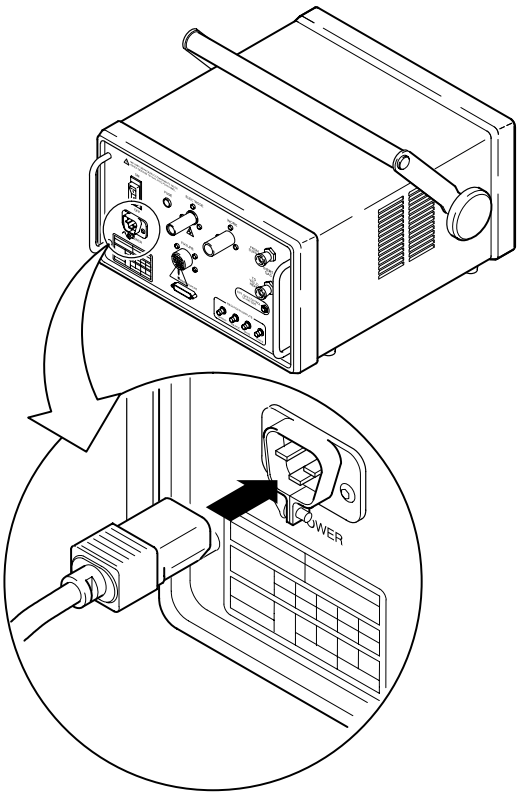


Figure 2-2 Power Cord Receptacle

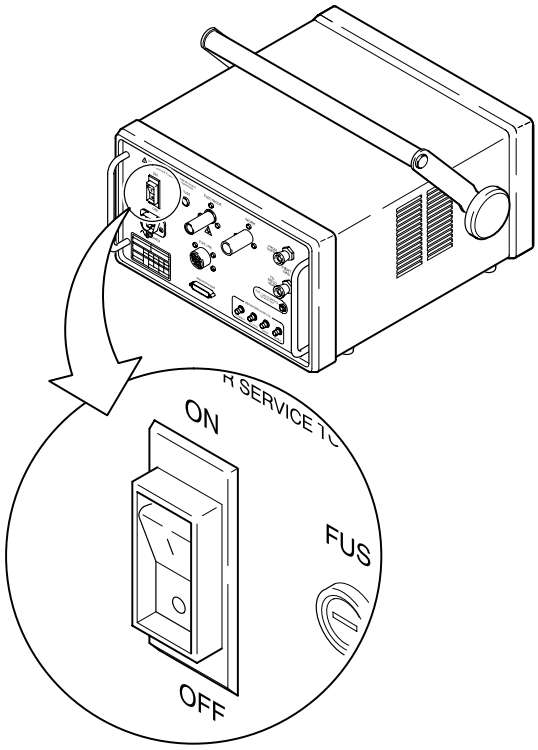


Figure 2-3 Power Supply Circuit Breaker in the OFF Position

Installing the SWS

To get the maximum performance and reliability from your SWS, it must be set up and installed properly.

This section describes how to

- install the power supply
- install the weld head.

Installing the Power Supply

To install the power supply, follow these steps:

1. Place the power supply in a position such that the front and rear panel controls are easily accessible.
2. Locate the power cord. Insert the cord into the polarized receptacle on the rear of the power supply. See Figure 2-2.
3. Tighten the connector lock at the base of the receptacle to secure the cord in the receptacle.
4. Ensure that the power cord reaches an electrical outlet. Do not connect the power cord to the outlet at this time.
5. Turn off the circuit breaker. Refer to Figure 2-3.

Installing the Weld Head

The weld head assembly has four connectors that plug into the power supply. See Figure 2-4.

The four connectors on the cable are

- fixture
- electrode (red)
- work (green)
- weld head shielding gas.

Connect the four connectors to the rear panel of the power supply by performing the following steps (see Figure 2-5):

1. Locate the weld head assembly.

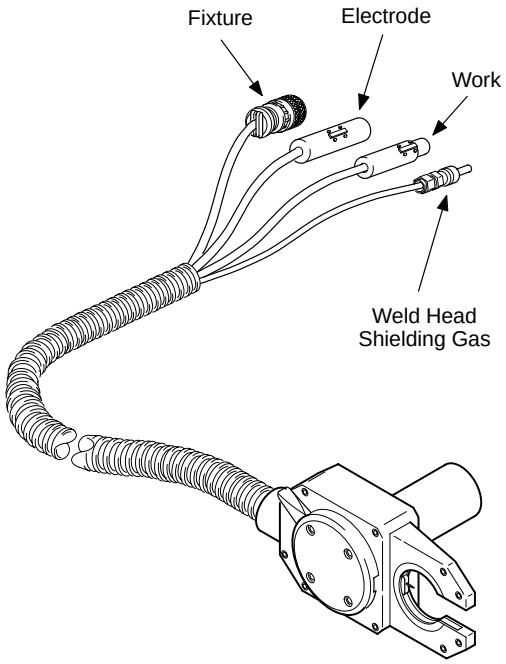


Figure 2-4 Weld Head Assembly

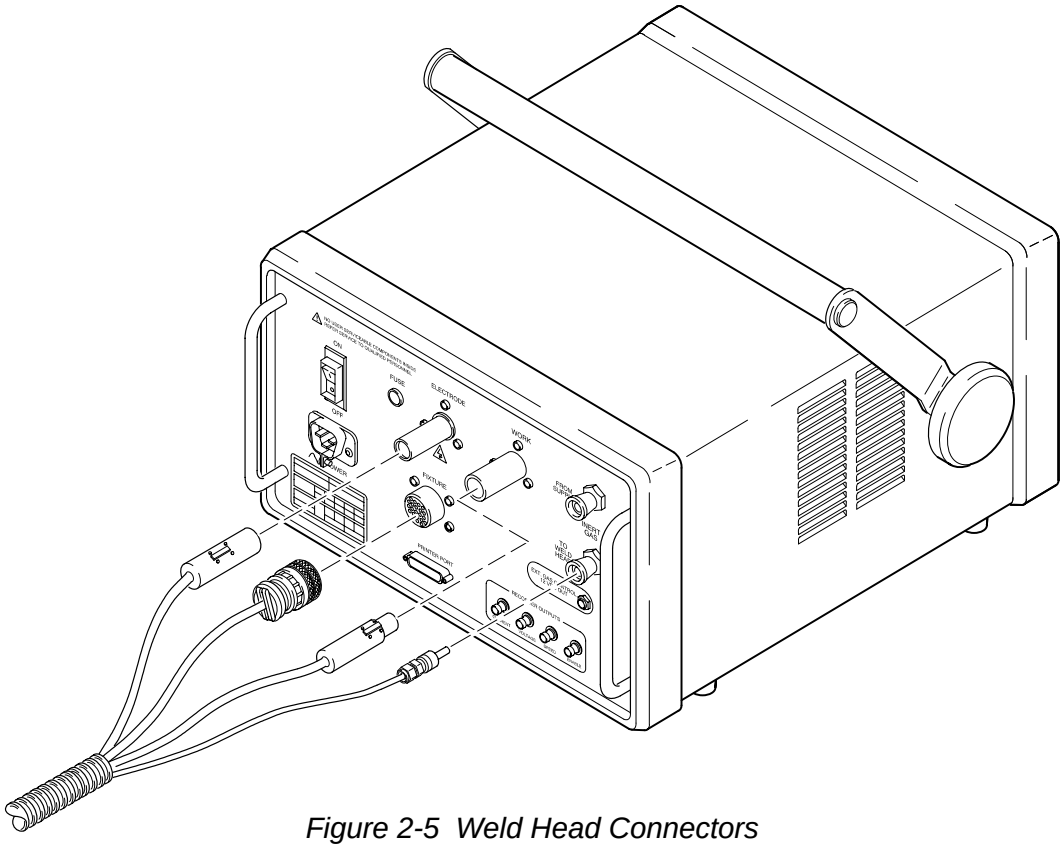


Figure 2-5 Weld Head Connectors

Caution!

Ensure that the fixture connector is fully seated in the mating socket and the threaded sleeve is tight.

2. Align the notch on the multi-pin connector with the small tab in the mating socket on the rear panel labelled FIXTURE. Insert the connector in the socket. Turn the connector sleeve clockwise by hand until it is tight. This connection provides the control signals to drive the weld head.

3. Insert and fully seat the red connector into the socket on the rear panel labelled ELECTRODE. Twist the connector 1/4-turn clockwise to lock it into place. This connection is the negative (−) output terminal of the weld head.

4. Insert the green connector into the socket on the rear panel labelled WORK. Twist the connector 1/4-turn clockwise to lock it into place. This connection is the positive (+) output terminal of the weld head.

Note: *The weld head shielding gas connector must be a single-end shut-off (SESO) Swagelok Quick-Connect stem (SS-QC4-S-400).*

5. Insert the weld head shielding gas connector into the Swagelok Quick-Connect stem labelled TO WELD HEAD. Ensure that the connector is firmly attached. This connection provides shielding gas to the weld head through a solenoid valve in the power supply.

Installing the Gas Delivery System

Introduction

The Gas Delivery System reduces oxidation or contamination to the weld puddle, tungsten electrode, and Heat Affected Zone (HAZ).

There are two types of gas delivery systems commonly used:

- typical Gas Delivery System

  Refer to the installation procedure beginning on page 2-10.

- gas delivery system using a secondary shielding gas solenoid valve

  Refer to the installation procedure beginning on page 2-12.

Installing the Typical Shielding/Purge Gas Delivery System

Install the Shielding/Purge Gas Delivery System. Figure 2-6 shows a typical system. Be sure to adhere to the following precautions:

- Ensure that the gas storage container(s) are secured before using them.
- Ensure all connections are tight and do not leak.
- Use only a Swagelok single-ended shut-off Quick-Connect stem on the shield/purge line for the shielding gas connector.
- Adjust the low-pressure regulator gage to reduce the gas storage container source pressure to 25 psig to 50 psig.

When complete, continue to the *Preliminary Check* procedure beginning on page 2-14.

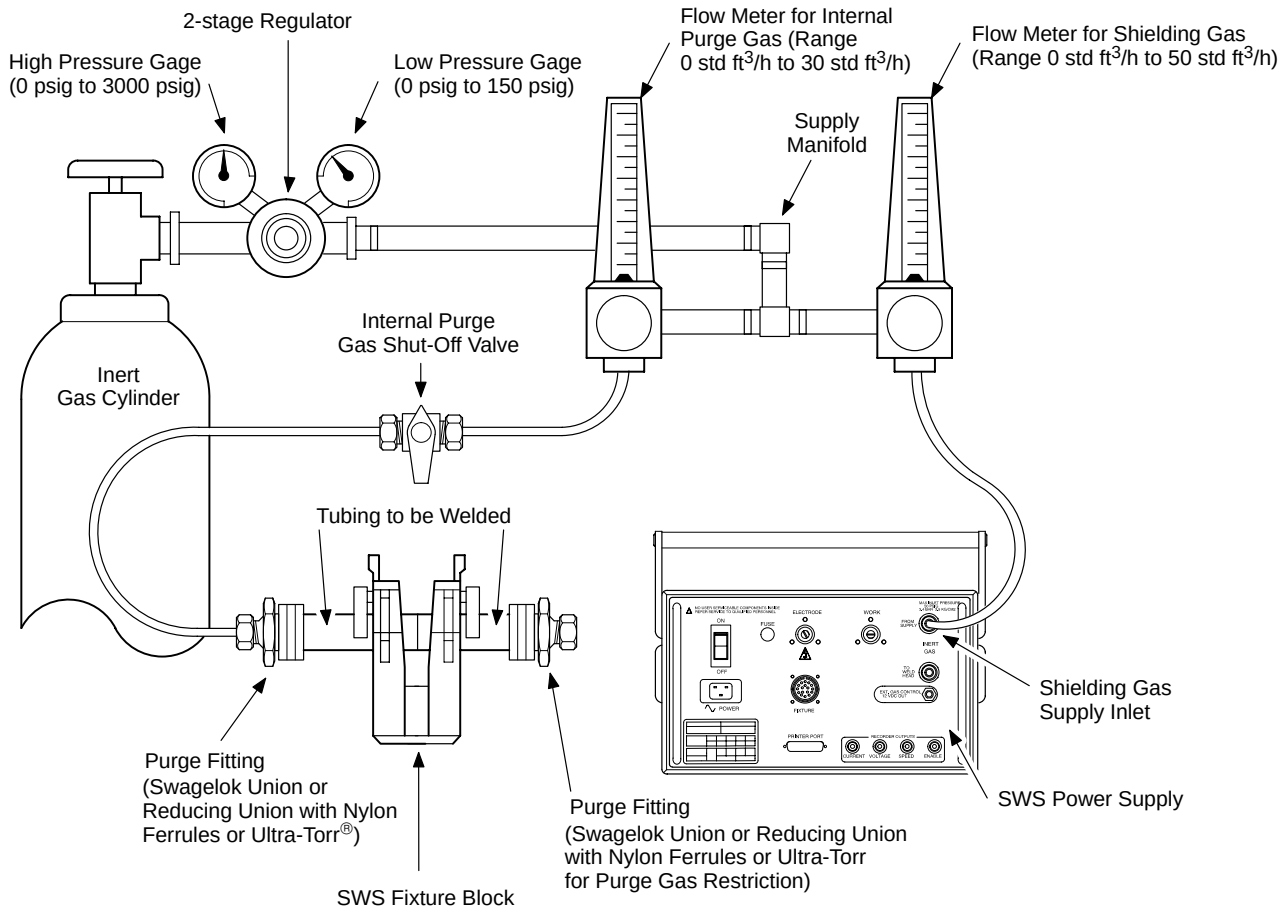


Figure 2-6 Typical Gas Delivery System

Installing the Optional Gas Delivery System

The optional gas delivery system is generally used in Ultra High Purity (UHP) gas systems where quick connects are not permitted. This type of system uses an external 12 V (dc) secondary solenoid valve instead of using the solenoid valve located inside the power supply. If necessary, the secondary solenoid valve may be the high purity type.

Caution!

Do not insert the secondary solenoid bypass plug into the connector unless you are using a secondary solenoid. Inserting the plug disables the power supply solenoid.

A secondary solenoid bypass plug is inserted in the EXT GAS CONTROL connector on the rear panel to disable the solenoid inside the power supply and provide +12 V to control the secondary solenoid.

For the gas delivery system using a secondary shielding gas solenoid valve, locate the:

- secondary solenoid bypass plug
- secondary shielding gas solenoid valve
- 1/4-turn internal purge gas shut-off valve.

Refer to Figure 2-7. Install the optional gas delivery system. Be sure to adhere to the following precautions:

- Ensure that the gas storage container(s) are secured before using them.
- Ensure all connections are tight and do not leak.
- Observe correct polarity on the secondary solenoid bypass plug.
- Adjust the low pressure regulator gage to reduce the gas storage container source pressure to 25 psig to 50 psig.

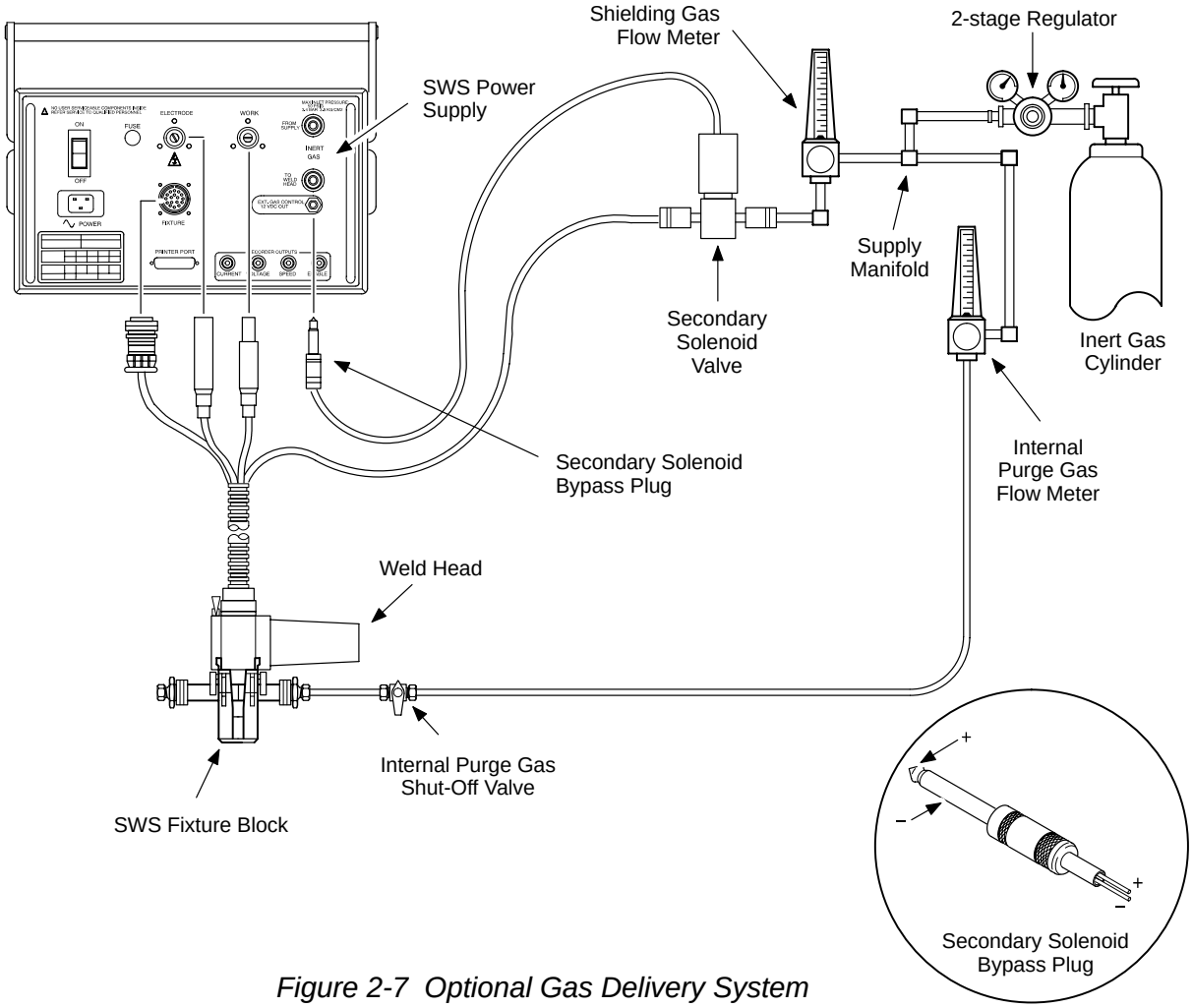


Figure 2-7 Optional Gas Delivery System

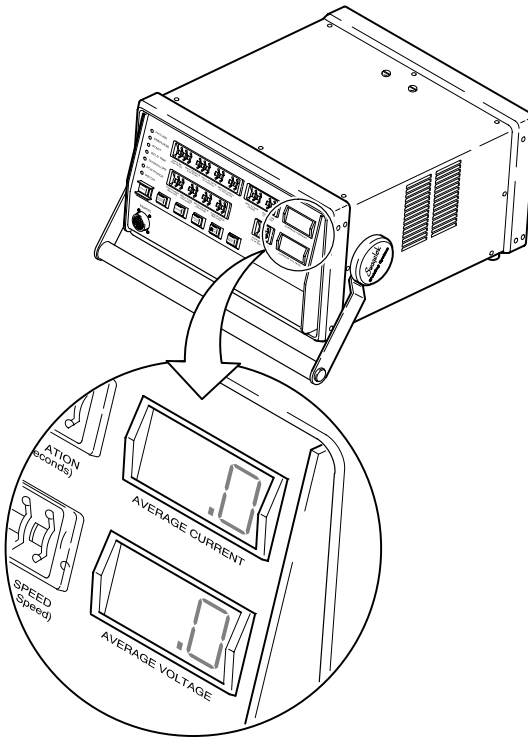


Figure 2-8 Average Current and Voltage Displays

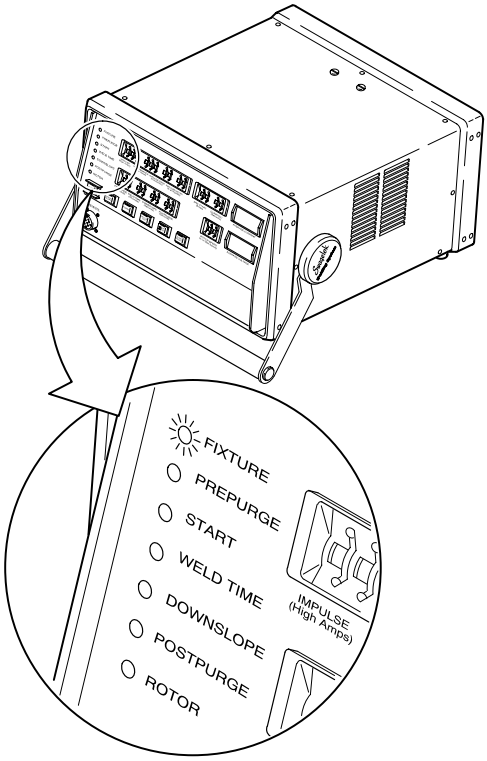


Figure 2-9 Weld Status Indicator Lights

Preliminary Check

Before placing the SWS into operation, you should check that the power supply is operating correctly.

To check the system, follow these steps:

1. Connect the power supply power cord to an electrical outlet.

2. Turn on the power supply circuit breaker. After a 2 second to 4 second delay, the following is displayed:

   - Blinking decimal point followed by a zero in the **Average Current** and **Average Voltage** displays on the power supply front panel. See Figure 2-8.
   - The amber-colored **Fixture** indicator light is on indicating that the fixture block is not attached to the weld head. See Figure 2-9.

If the power supply does not come on, refer to Section 7, *Troubleshooting*, for a list of possible causes and corrective actions.

3. Position the weld head such that the rotor can be easily seen. See Figure 2-10.

4. Press **STOP/RESET** on the front panel.

    - For series 5, 10, and 20 Weld Heads, the rotor should make one-half of a rotation (180° position) in the head. See Figure 2-11.
    - For the micro head, the rotor should make one complete rotation in the head.

5. Press **STOP/RESET** on the front panel to return the rotor to its home position.

6. Turn off the power supply.

If problems occur, refer to Section 7, *Troubleshooting*, for a list of possible causes and corrective actions.

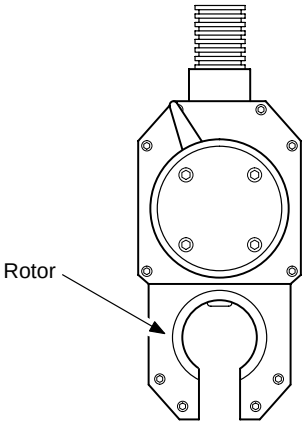


Figure 2-10 Positioning the Weld Head to View the Rotor Rotation

Note: *The rotor must be returned to its home position before welding.*

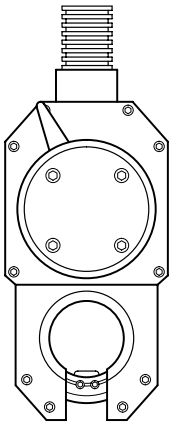


Figure 2-11 Checking the Rotor Rotation

Section 3
Operation

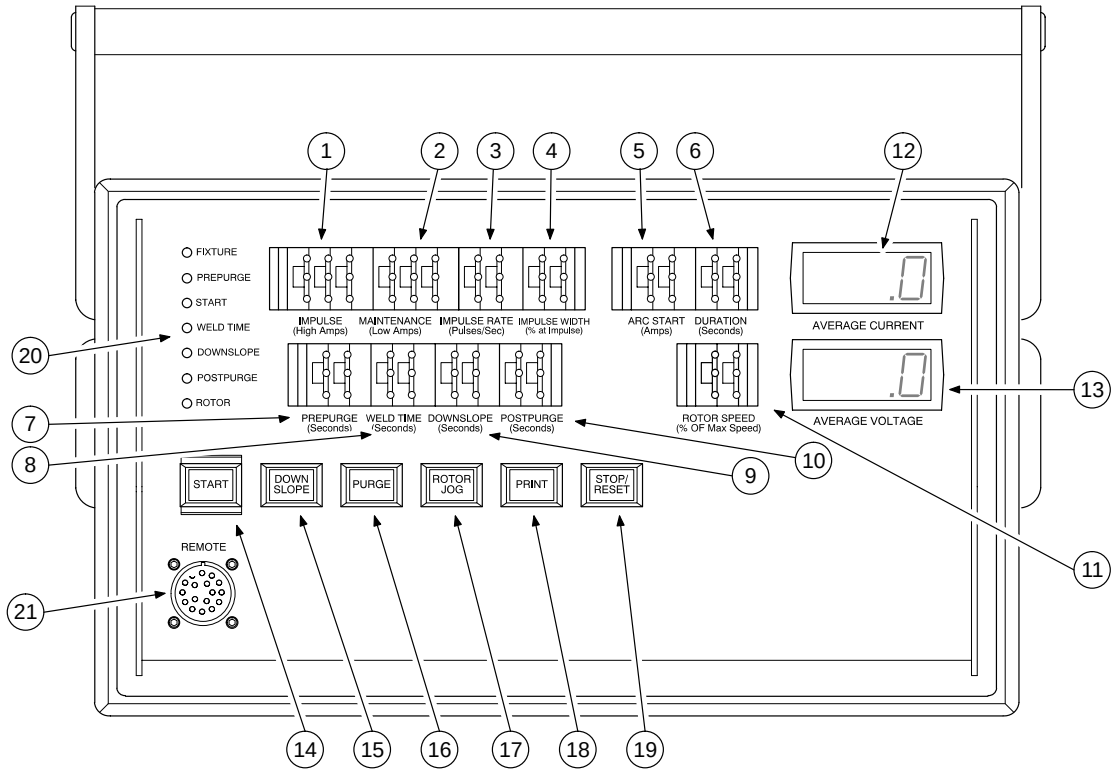
Introduction

This section describes the basic operation of the Swagelok Welding System (SWS). This section includes

- front panel controls
- SWS modes of operation
- installing the electrode in the Series 5/10/20 Weld Head
- setting the arc gap
- preparing the work
- fixturing the work
- connecting the weld head to the fixture block
- entering the weld parameters
- setting the shield gas flow
- starting and completing the weld.

The description of the welding process in this section uses a weld procedure guideline based on tubing with a 1/2 in. OD and 0.049 in. wall thickness. Remember that a weld procedure guideline is a list of weld parameter settings that have been determined for a particular job. Keep in mind that the weld parameters listed in this section may not produce an optimum weld since the purpose of this section is to demonstrate the operation of the SWS. Section 5, *Weld Parameter Adjustment,* describes how to optimize welding parameters.

Front Panel Controls



1. Impulse rotary switch
2. Maintenance rotary switch
3. Impulse Rate rotary switch
4. Impulse Width rotary switch
5. Arc Start rotary switch
6. Duration rotary switch
7. Prepurge rotary switch
8. Weld Time rotary switch
9. Downslope rotary switch
10. Postpurge rotary switch
11. Rotor Speed rotary switch
12. Average Current display
13. Average Voltage display
14. Start pushbutton
15. Downslope pushbutton
16. Purge pushbutton
17. Rotor Jog pushbutton
18. Print pushbutton
19. Stop/Reset pushbutton
20. Status indicator lights
21. Remote Pendant connector

Figure 3-1 Front Panel Controls

You operate the SWS by using pushbuttons and rotary switches on the front panel of the power supply. The values you program into the rotary switches are determined by the weld procedure guidelines.

The front panel digital displays monitor the welding process and show message code information. Message codes are numbers that indicate weld parameter setup errors, power supply status, etc.

The status indicator lights on the front panel show the welding process sequence or flash a warning if the power supply detects that a weld parameter is set incorrectly.

Current Control Switches

The current control switch group determines the characteristics of the current output of the power supply during a weld cycle. See Figure 3-2. The controls function as follows:

- **IMPULSE** (High Amps) sets the maximum current output used during the weld cycle. The impulse setting affects the depth of penetration of the weld profile.
- **MAINTENANCE** (Low Amps) sets the minimum current output used during the weld cycle. This is the current level required to
  - maintain the arc
  - provide enough background heat to maintain the weld puddle.
- **IMPULSE RATE** (Pulses/Sec) sets the number of changes per second between the Impulse and Maintenance current levels during the weld cycle.
- **IMPULSE WIDTH** (% of Impulse) sets the percentage of time the current is at the Impulse current level for each Impulse/Maintenance cycle.
- **ARC START** (Amps) sets the output current during the duration period. This current level
  - helps stabilize the initiated arc
  - develops the weld puddle.

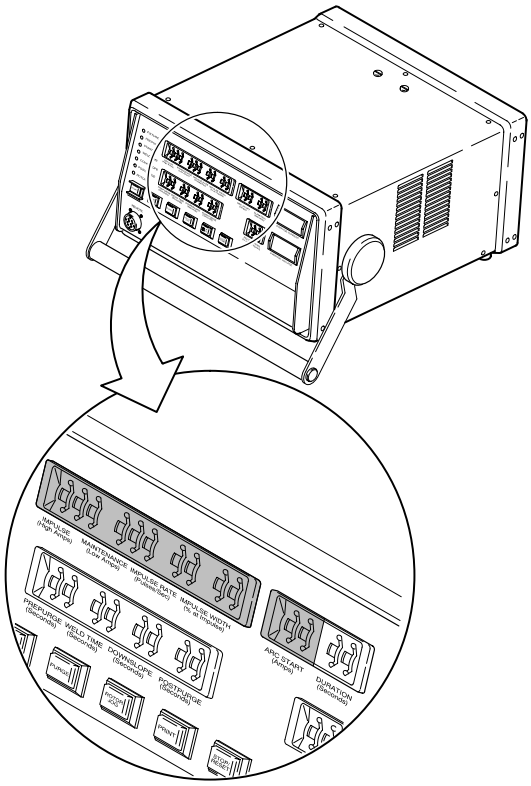


Figure 3-2 Current Controls

Timing Control Switches

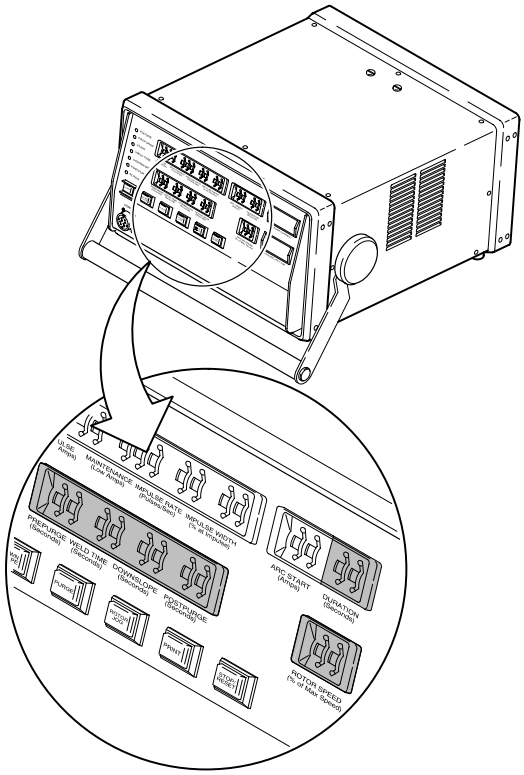


Figure 3-3 Timing Controls

The timing control switch group determines the weld cycle timing. See Figure 3-3. The controls function as follows:

- **PREPURGE** (Seconds) is the time in which shielding gas flows through the weld head and around the weld joint before the arc is initiated.
- **DURATION** (Seconds) is the length of time between the arc start period and the beginning of the weld time cycle.
  - The current specified on the arc start rotary switch is maintained during this time.
  - The rotor does not move during this time.
- **WELD TIME** (Seconds) is the actual welding time at the average current. During the weld time, the output current cycles between the impulse and maintenance levels at the impulse rate and impulse width entered.
  - During this time, the rotor moves at the speed specified by the rotor speed rotary switch.
  - The weld time cycle forms the main body of the weld.
- **DOWNSLOPE** (Seconds) is the time during which the average weld current uniformly decreases until the arc is extinguished.
  - During this time, the rotor continues to move at the speed specified by the rotor speed rotary switch.
  - The downslope cycle reduces the chance of weld cracking.

- **POSTPURGE** (Seconds) is the amount of time the shielding gas continues to flow through the weld head and around the weld joint after the arc is extinguished. This gas flow prevents oxidation and contamination of the weld bead and electrode while the work is cooling.
- **ROTOR SPEED** (% of Max Speed) is expressed as a percentage of the maximum RPM that the rotor can attain. A rotor speed setting of 99 gives the maximum RPM for the weld head. See Table 3-1.

Table 3-1 Maximum Rotor Speed by Weld Head Model

Weld Head Model	Maximum Rotor Speed (RPM)	Seconds/ Revolution
Micro Weld Head	24	2.5
Series 5/10 Weld Head	12	5
Series 20 Weld Head	6	10

Note: *A minimum of 10 seconds* **PREPURGE** *is recommended for all SWS Weld Head models. If Weld Head extension cables are used, add one second for each foot of cable added.*

Pushbuttons

The front panel pushbuttons control the welding operation and provide some manual control functions for the weld head. See Figure 3-4. The pushbutton functions are as follows:

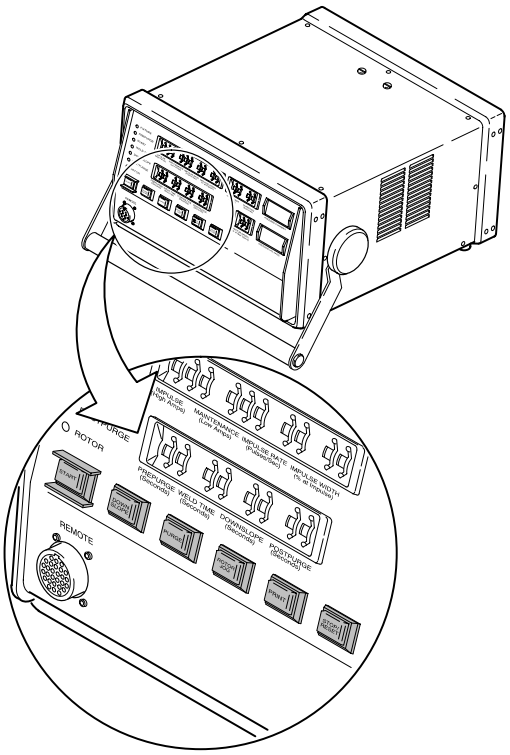


Figure 3-4 Pushbuttons

- **START** initiates the welding sequence.
- **DOWNSLOPE** initiates the downslope cycle when pressed during the weld time cycle. The downslope cycle reduces the output current levels from the weld time levels to zero during the time specified.
- **STOP/RESET** aborts the weld and halts the rotor if pressed during the weld cycle. Push **STOP/RESET** again to return the rotor to its home position as shown in Figure 3-5 on page 3-7. The rotor will move at maximum speed when traveling to the home position, regardless of the programmed rotor speed. When not welding, pushing **STOP/RESET** causes the rotor to rotate as shown in Table 3-2.

Table 3-2 Stop/Reset Rotor Travel

Weld Head Model	Rotor Travel
Micro Weld Head	1 Revolution
Series 5, 10, 20	1/2 Revolution (no Fixture Block connected)
	1 Revolution (with Fixture Block connected)

- **PURGE** activates the internal solenoid valve or the optional external gas solenoid valve and starts the flow of shielding gas to the weld head. See **Note**. When **PURGE** is depressed, shielding gas flows to the weld head until you press the pushbutton again. The pushbutton overrides the prepurge and postpurge timers and allows shielding gas to continuously flow through the weld head.

Note: *The external gas solenoid referenced here may be used in place of the internal solenoid at the user's option.*
See Section 2, Installation, *for installation information.*

- **ROTOR JOG** advances the rotor manually. Press and hold the pushbutton to move the rotor. Release the pushbutton to stop the rotor. **ROTOR JOG** can be used to position the rotor for electrode replacement or adjustment. The rotor will move at the speed defined by the **ROTOR SPEED** rotary switches.
- **PRINT** causes the power supply controller to transmit weld data to the printer port on the rear of the unit. The optional CWS-DRP printer accepts the data and prints the record.

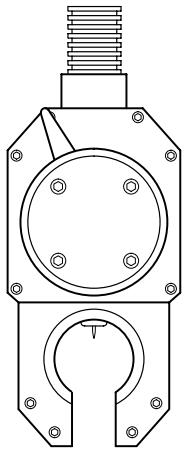


Figure 3-5 Rotor Home Position

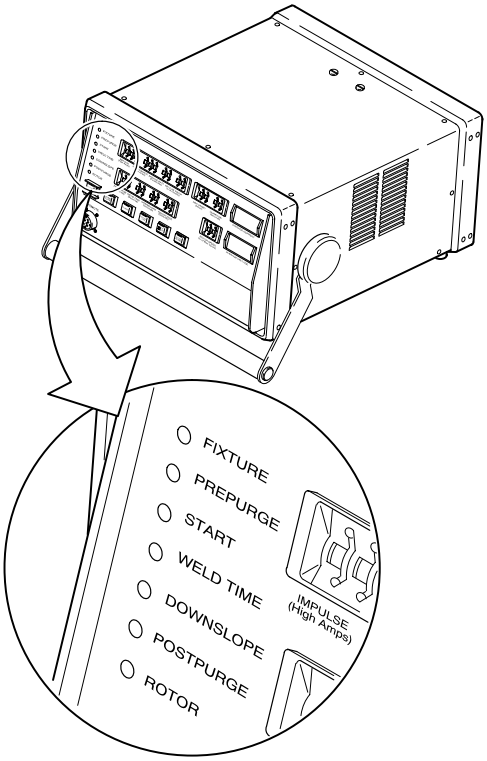


Figure 3-6 Status Indicator Lights

Status Indicator Lights

The status indicator lights monitor certain elements of the power supply operation. See Figure 3-6.

The conditions monitored by some of the indicators are independent of the welding process. Most of the indicators light during the welding process to show the control sequence executed by the power supply. The control sequence is affected by the values entered into the timing control switches.

The lights also notify you if any weld parameter settings exceed pre-defined limits. See Figure 3-8 for an example.

- **Fixture** indicates whether or not the weld head is properly attached to the fixture block. If it is not connected, the indicator light is on. The power supply will not start a weld cycle when this indicator light is on.
- **Prepurge** indicates the prepurge cycle is active. The Prepurge cycle occurs prior to arc start. This light indicates that the shielding gas solenoid valve in the power supply is energized, allowing the shielding gas to flow to the weld head prior to starting the welding cycle.
- **Start** indicates the power supply is in the arc start portion of the weld cycle.
- **Weld time** indicates the weld cycle is in progress.
- **Downslope** indicates the downslope cycle is in progress.
- **Postpurge** indicates the postpurge cycle is in progress. The shielding gas continues to flow to the weld head, and the rotor moves to the home position.
- **Rotor** indicates the rotor is in motion.

Caution!

DO NOT try to remove the fixture block from the weld head until all status indicator lights are off.

Digital Displays

The digital displays monitor system operation during welding and provide message code information. See Figure 3-7. The display functions are as follows:

- **Average Current** indicates the average arc current measured during the weld sequence.
- **Average Voltage** indicates the average arc voltage measured during the weld sequence.

  The average voltage displayed during a weld cycle varies with the arc gap, type of shielding gas, current output, etc., but typically is in the 5 V to 15 V range.

The **Average Current** and **Average Voltage** displays are also used for programming and displaying message codes. See *SWS Modes of Operation*.

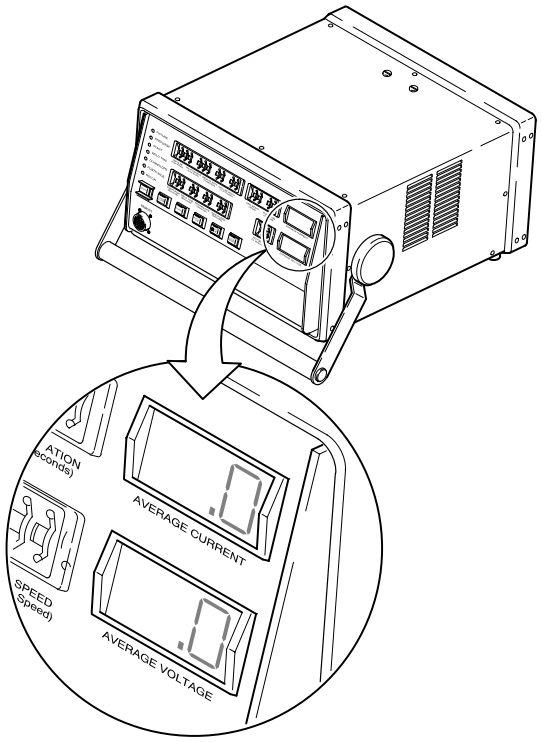


Figure 3-7 Digital Displays

SWS Modes of Operation

The front panel controls serve two purposes. In addition to controlling the weld parameters and weld sequences, the controls are used to access the modes of the power supply.

The power supply has three modes of operation:

- operational
- program
- test

Each mode uses message codes to perform a variety of functions. Generally, the message codes are grouped by mode. Operational mode uses codes 1 to 11, 41, 42, 50, and 51. Program mode uses 20 to 23, 30 to 35, 60 to 63, and 99. Test mode uses 97 and 98.

The message codes are explained in detail later in this section.

Table 3-3 shows all the message codes used by the power supply. Note that certain code ranges are marked Factory Use. These codes, except for 64 to 96, are normally not used, which is noted in the table.

Table 3-3 SWS Message Codes

Code No.	Name	Normal Operating Range	Mode or Setting to Activate	Code Type
01	Impulse	2 A to 99.9 A	< 2	Disable*
02	Maintenance	2 A to 99.9 A	< 2	Disable*
03	Impulse Rate	1 Hz to 99 Hz	< 1	Caution
04	Impulse Width	5 % to 95 %	< 5 or > 95	Disable*
05	Arc Start	2 A to 99 A	< 2	Disable*
06	Duration	0.0 to 5.0	> 5.0	Disable*
07	Prepurge	1 s to 99 s	< 1	Caution
08	Weld Time	1 s to 99 s	< 1	Disable*
09	Downslope	1 s to 99 s	< 1	Disable*
10	Postpurge	1 s to 99 s	< 1	Caution
11	Rotor Speed	5 % to 99 %	≥ 1 or < 5	Caution
			< 1	Disable*
12 to 19	Factory use			Not used
20	Resettable weld counter	0 to 9999	Program mode	Programmable
21	Automatic print counter	0 to 99	Program mode	Programmable
22	Enable signal polarity	0=low 1=high	Program mode	Programmable
23	Arc Start power	0=low 1=normal	Program mode	Programmable
24 to 29	Factory use			Not used
30	Time - hours	0 to 24	Program mode	Programmable
31	Time - minutes	0 to 59	Program mode	Programmable
32	Date - month	1 to 12	Program mode	Programmable
33	Date - day	1 to 31	Program mode	Programmable
34	Date - year	2 digit 00=2000	Program mode	Programmable
35	Date printing format	0=mm/dd/yy 1=dd/mm/yy	Program mode	Programmable
36 to 40	Factory use			Not used
41	Paper out		No paper installed with printer power on	Caution

Code No.	Name	Normal Operating Range	Mode or Setting to Activate	Code Type
42	Printing		Data is transferred to printer port	Information only
43 to 49	Factory use			Not used
50	Hi-temp		Excessive internal power supply temperature	Disable*
51	Old head type		No weld head or non-safety interlocked weld head connected	Disable*
52	Rotor jam		Rotor motion impeded	Disable* See Note (A)
53 to 59	Factory use			Not used
60	Non-resettable weld counter		Program mode	Information only
61	Arc start attempts		Program mode	Information only
62	System serial number		Program mode	Information only
63	System software version		Program mode	Information only
64 to 96	Factory use			See Note (B)
97	Test switches/ pushbuttons		Test mode	
98	Test indicator lights/displays		Test mode	
99	Print user parameters		Program mode	

***** The Prepurge, Start, Weld Time, Downslope, and Postpurge status indicator lights are flashing.

Note (A): Press **STOP/RESET** to clear the error. Rotor will not move again unless **STOP/RESET** is pressed a second time.

Note (B): Service may be necessary. Call your Swagelok representative.

Operational Mode

When the power supply is turned on it enters the operational mode. The **Average Current** and **Average Voltage** displays show a blinking decimal point and a zero. If the weld head is not attached to a fixture block, **Fixture** is on. The power supply is ready to be used.

Weld Parameter Limits (Message codes 1 to 11)

Each front panel rotary switch controls a part of the welding process. The power supply operates normally as long as each switch setting is within certain limits. If the limits are exceeded, the power supply reacts to the condition and shows a message code on the front panel displays. If the code display is accompanied by flashing status indicator lights, a “disable” condition exists. If not, the code display indicates a “caution” condition.

Message codes 1 to 11 refer to the front panel rotary switches by number. See Table 3-4. See Figure 3-1 to cross reference the switch position numbers.

Table 3-4 Weld Parameter Limit Message Codes

Code No.	Name	Normal Operating Range	Mode or Setting to Activate	Code Type
01	Impulse	2 A to 99.9 A	< 2	Disable*
02	Maintenance	2 A to 99.9 A	< 2	Disable*
03	Impulse Rate	1 Hz to 99 Hz	< 1	Caution
04	Impulse Width	5 % to 95 %	< 5 or > 95	Disable*
05	Arc Start	2 A to 99 A	< 2	Disable*
06	Duration	0.0 to 5.0	> 5	Disable*
07	Prepurge	1 s to 99 s	< 1	Caution
08	Weld Time	1 s to 99 s	< 1	Disable*
09	Downslope	1 s to 99 s	< 1	Disable*
10	Postpurge	1 s to 99 s	< 1	Caution
11	Rotor Speed	5 % to 99 %	≥ 1 or < 5	Caution
			< 1	Disable*

***** The Prepurge, Start, Weld Time, Downslope, and Postpurge status indicator lights are flashing.

Disable Condition

The power supply enters a “disable” condition when a serious fault exists or a front panel control is set to a value that could damage the system. The power supply will not start in a “disable” condition. The rotor can still be moved while the “disable” condition exists, using **STOP/RESET** or **ROTOR JOG**. The power supply shows the “disable” condition by flashing the status indicator lights shown in Figure 3-8 and flashing a message code on the **Average Current** and **Average Voltage** displays. The code shows you what rotary switch is misprogrammed.

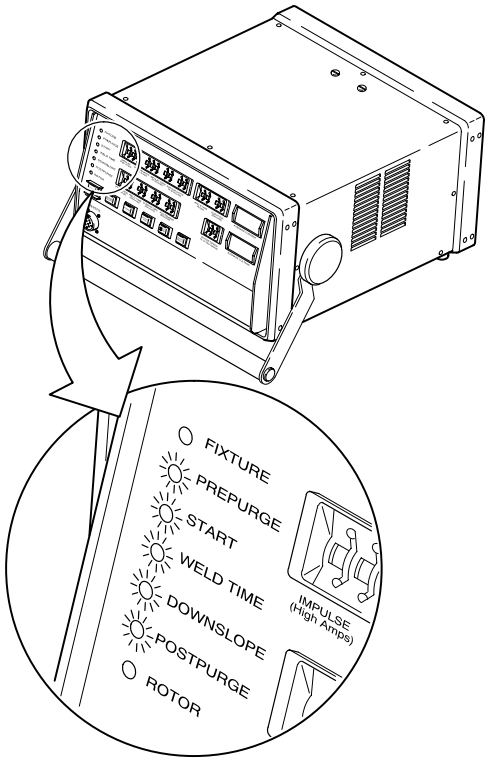


Figure 3-8 Disable Condition

Caution Condition

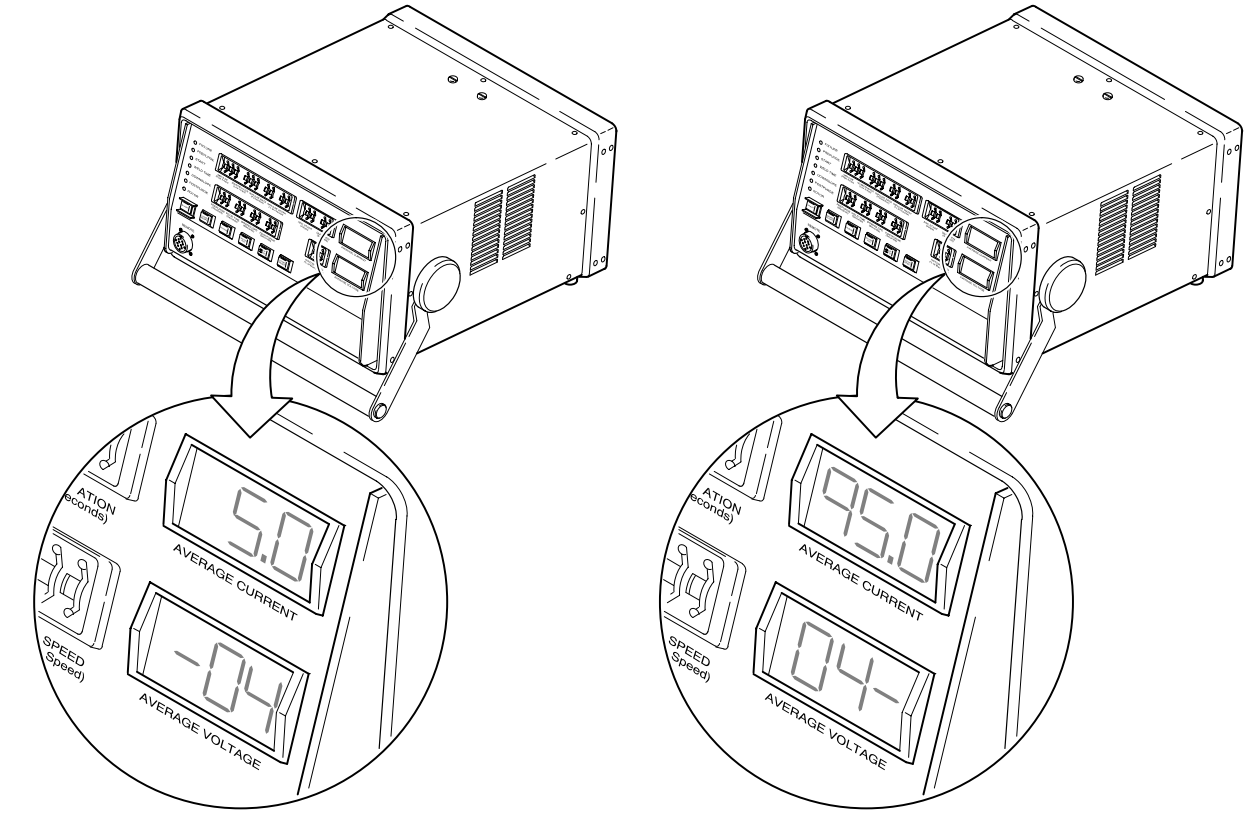
A “caution” condition indicates that a front panel parameter setting is questionable. The power supply is not disabled and can weld if a “caution” exists. The front panel indicates a “caution” condition by flashing a message code on the **Average Current** and **Average Voltage** displays. The code shows you which rotary switch has the questionable value.

Interpreting the Message Codes

The power supply shows the switch setting problem by displaying the switch code on the **Average Voltage** display. Codes 1 to 11 use the **Average Current** display to show the limit for the switch identified by the **Average Voltage** display. Code numbers 41 and above in the **Average Voltage** display are system status information or errors detected by the power supply.

See Figure 3-9. The **Average Voltage** display shows that rotary switch position 04 has an incorrect value. Refer to Figure 3-1 and note that the switch labeled 04 is the **IMPULSE WIDTH** switch. The position of the dash indicates which limit is exceeded, minimum or maximum. Figure 3-9(A) shows the dash on the left, indicating that the setting is too low. Figure 3-9(B) shows the dash on the right, indicating the setting is too high.

The **Average Current** display shows the limit for the parameter. Whether the limit displayed is a minimum or maximum depends on the position of the dash in the other display. Figure 3-9(A) shows the low limit for **IMPULSE WIDTH** is 5. Figure 3-9(B) shows the high limit for **IMPULSE WIDTH** is 95.



(A) Dash on left indicates below minimum

(B) Dash on right indicates above maximum

Figure 3-9 Digital Display Examples for the Operator/Machine Interface

Multiple Disable or Caution Conditions

The power supply displays multiple errors on the digital displays one after another. Each message code is displayed for a moment, followed by the next, until all are shown. The sequence repeats continuously until the errors are cleared.

If the message code is caused by a “disable” condition, the status indicator lights blink as the code is displayed.

System Status/Faults (Message codes 41 to 52)

41 Paper out

Code 41 indicates that the optional printer is out of paper. See Appendix B, *Optional Equipment,* for information on the printer.

42 Printing

Code 42 appears when a print cycle is started. The power supply outputs data to the optional printer. This code only shows that the data is being sent to the printer. The power supply does not monitor the printer operation.

50 Hi-temp

Code 50 is a “disable” condition that is not resettable. The condition occurs when a temperature sensor inside the power supply detects a buildup of heat that exceeds a predefined limit. The power supply is disabled until the internal temperature drops to a safe level. Allow the power supply to cool. After the condition clears, welding can resume.

51 Old head type

Code 51 is a “disable” condition. The code is displayed if the power supply does not detect a safety interlocked weld head. The code is displayed if no weld head is connected or if a nonsafety interlocked weld head is connected.

52 Rotor jam

Code 52 is a “disable” condition. The condition occurs if the power supply senses that the rotor motion is impeded. The power supply monitors the rotor when a move command is given. If no motion is detected, the code is displayed, and the system is disabled.

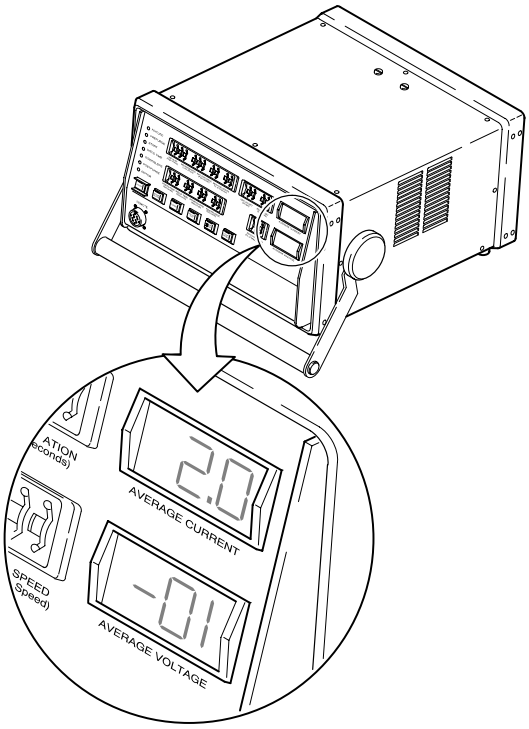


Figure 3-10 Display Readout for Example 1

Let's look at two examples:

EXAMPLE 1 − Disable Condition

Suppose a weld procedure guideline is keyed in and **IMPULSE** is set to 1 A. The minimum allowable Impulse setting (message code 01) is 2 A, so the power supply is disabled and the status indicator lights begin to flash. Pressing **START** has no effect. The rotor can still be moved with **ROTOR JOG** or **STOP/RESET**.

The digital displays read as shown in Figure 3-10. The **Average Voltage** display shows that switch one (Impulse) is below its minimum allowable setting (dash on left). The **Average Current** display shows the minimum limit is 2 A.

By changing the value of the Impulse switch to 2 A or greater, the condition is corrected and the operation can proceed. The correct Impulse value can only be determined by developing a proper weld procedure guideline.

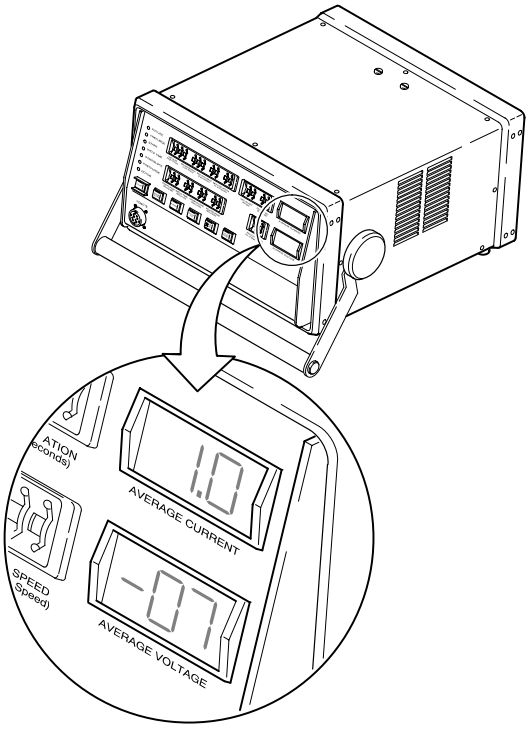


Figure 3-11 Display Readout for Example 2

EXAMPLE 2 − Caution Condition

A weld procedure guideline is keyed in and **Prepurge** is set to zero seconds. You may wish to use a continuous purge, so the prepurge timer is not needed. The minimum prepurge setting (message code 07) is one second. According to Table 3-3, code 07 will not disable the power supply, so entering zero creates a "caution" condition.

The digital displays read as shown in Figure 3-11. The **Average Voltage** display shows that switch 7 (Prepurge) is below its normal limit (dash on left). The **Average Current** display shows the minimum limit is one.

The unit is still functional. This condition only serves to show that there is a questionable setting. If **START** is pushed, the system begins welding, and the weld current and voltage are displayed. After completing the weld, the digital displays again indicate the caution condition. When **Prepurge** is changed to one second or greater, the displays return to normal.

Program Mode

The program mode accesses setup parameters for the power supply and the optional printer. The program mode also serves as an access path for the test mode. See “Test Mode” on page 3-22.

Entering Program Mode

Refer to Figure 3-12. Do the following to enter program mode:

1. Press and hold **DOWNSLOPE**.
2. Press and hold **ROTOR JOG**.
3. Release both pushbuttons at the same time.

The status indicator lights begin to sequence up and down, indicating that the program mode has been successfully entered.

Selecting Program Items

In program mode, the **ROTOR SPEED** rotary switch is the code number selector. Enter a number into the switch, and the code number is shown on the **Average Voltage** display. Data associated with the code number will be displayed on the **Average Current** display.

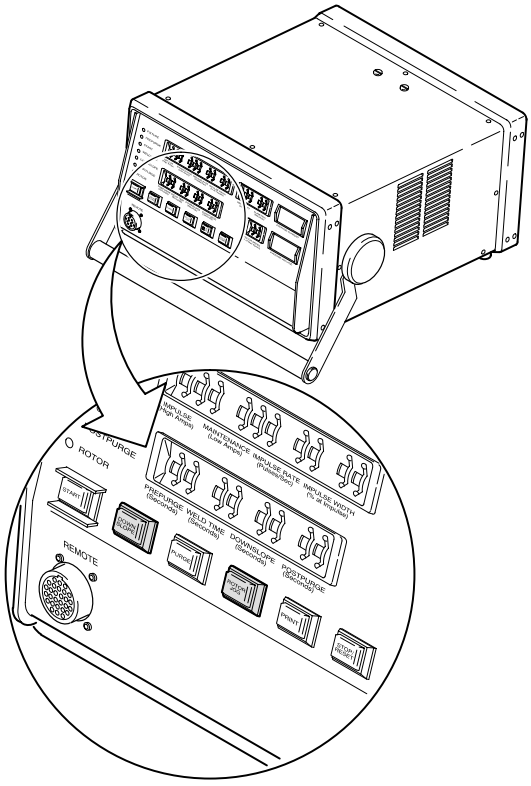


Figure 3-12 Entering Program Mode

Codes selected by the **ROTOR SPEED** switch may be able to be programmed, such as time and date information, or be a read-only parameter, such as the system serial number. See Table 3-5 for a list of all code numbers.

Table 3-5 Program Mode Code Numbers

Code No.	Description	Programmable
20	Resettable weld counter	Yes
21	Automatic print counter	Yes
22	Enable signal polarity	Yes
23	Arc Start power	Yes
30	Time − hours	Yes
31	Time − minutes	Yes
32	Date − month	Yes
33	Date − day	Yes
34	Date − year	Yes
35	Date printing format	Yes
60	Nonresettable weld counter	No
61	Arc start attempts	No
62	System serial number	No
63	System software version	No
99	Print user parameters	No

Code Number Descriptions

20 *Resettable weld counter*

The resettable weld counter counts the number of valid weld cycles completed. The counter can be preset to any number from 0 to 9999. The controller increments the counter each time a valid weld cycle occurs. A weld cycle must last longer than 1.5 seconds to be considered valid. The counter number will be printed on the weld data record. See the description of the optional printer in Appendix B, *Optional Equipment*.

21 *Automatic print counter*

The print counter allows the power supply to automatically print a weld data record at regular intervals. The interval is set by the value entered in the counter. Entering a value of ten, for example, causes the power supply to print a weld data record for weld cycle 10, 20, 30, and so on. The power supply stores the weld count in memory. The weld count will be reset if a new print count value is entered. The weld count is also reset when the power supply is turned off.

The default print counter value is zero. Zero in the counter disables the feature.

A weld data record printout can be accomplished at any time by pushing **PRINT** on the front panel. See the printer description in Appendix B, *Optional Equipment,* for an example of the printout.

22 *Enable signal polarity*

The Enable signal, one of the BNC data recording outputs described in Appendix B, *Optional Equipment*, has a selectable polarity. Set item 22 to a value of 1 to make the signal active HIGH. A value of 0 in item 22 causes the signal to be active LOW. See Appendix B, *Optional Equipment,* for more information on data recording.

23 *Arc Start power*

The Arc Start power setting changes the Arc Start power level.

The default setting for Arc Start power is one (normal power). This setting is recommended for all tubing with an OD greater than 1/16 in. (1,5 mm) or a wall thickness greater than 0.020 in. (0,5 mm).

Set the Arc Start power to zero (low power) for tubing with a 1/16 in. (1,5 mm) OD or wall thickness under 0.020 in. (0,5 mm). Using the normal power setting for work of this size can affect the integrity of the weld. The **ARC START** and **DURATION** rotary switch settings may have to be increased when Arc Start power is set to zero.

30-35 *Time and date*

The controller in the power supply keeps track of the time and date. Display or change the current settings using items 30 through 35.

Code 30 is the hour, using the 24-hour format. Code 31 is the minutes, 32 is the month, 33 is the day, and 34 is the year. Each item is a two-digit value. A 00 entered for the year indicates the year 2000.

Code 35 sets the date format for a printout. A value of zero, which is the default, sets the date to the mm/dd/yy format. A value of one sets the format to dd/mm/yy.

60-63 *Weld system information*

Code 60 is a non-resettable weld counter. This counter tracks any weld cycle lasting longer than 1.5 seconds. Its maximum value is 999 999.

Code 61 is a counter tracking arc start attempts. Any attempt to start an arc will increment the counter. This counter is also not resettable. The value will be greater than or equal to the weld count in item 60.

Code 62 displays the serial number of the power supply. The value is set at the factory and cannot be changed.

Code 63 displays the version of the controller software. A value of 400 means version 4.00.

Note: *The controller does not check the state of the printer during execution of a print cycle. The user parameters are sent to the printer port when* **ROTOR JOG** *is pressed.*

99 *Print user parameters*

Code 99 causes the system to output all user parameters to the optional printer. See the description in Appendix B, *Optional Equipment,* for an example of the printout. After entry, press **ROTOR JOG** to start the print cycle. **Average Voltage** will show the number 42 while data is being sent to the printer.

Changing Program Mode Items

The **ARC START** and **DURATION** switches are used for programming values into the power supply. If a code number requires a two-digit value, only the **DURATION** switch is used to input values. If a data value has more than two digits, **ARC START** is used to set the most-significant two digits and **DURATION** sets the least-significant two digits. See Figure 3-13.

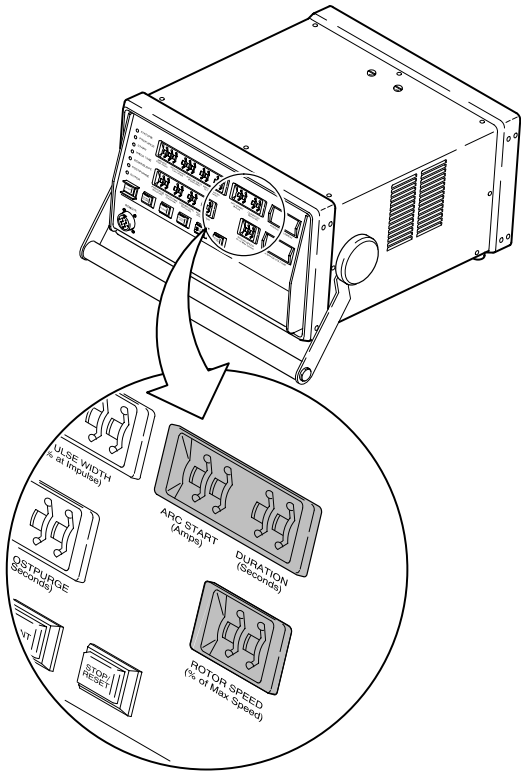


Figure 3-13 Data Entry Switches

The **Average Current** display shows the current value of the item. After a new value is entered, the display changes to reflect the new value.

The following example uses the resettable weld counter, code 20, to illustrate how a code value is changed. The example shows how to set the weld counter to a value of 1000. Do the following to modify the value:

1. Press and hold **DOWNSLOPE**.
2. Press and hold **ROTOR JOG**.
3. Release both pushbuttons at the same time.

   The SWS is now in program mode.
4. Enter 20 into **ROTOR SPEED**.
5. Enter 10 into **ARC START**. Enter 00 into **DURATION**.
6. Press and hold **ROTOR JOG** for 2 seconds to 3 seconds to enter the new value. When the status indicator lights begin to flash, release the pushbutton.

   When **ROTOR JOG** is pressed, all the status indicator lights will turn on. After a small delay, the lights start to flash, indicating the change has been completed. The **Average Current** display now shows the new value.

Since the **Average Current** display is limited to three digits, values greater than 999 must be displayed in two parts. First, the most-significant digits are displayed. After a moment, the three least-significant digits are displayed, with a decimal point by the last digit. For this example, 1 would be displayed first, followed by 000., to show the value of 1000. See Figure 3-14.

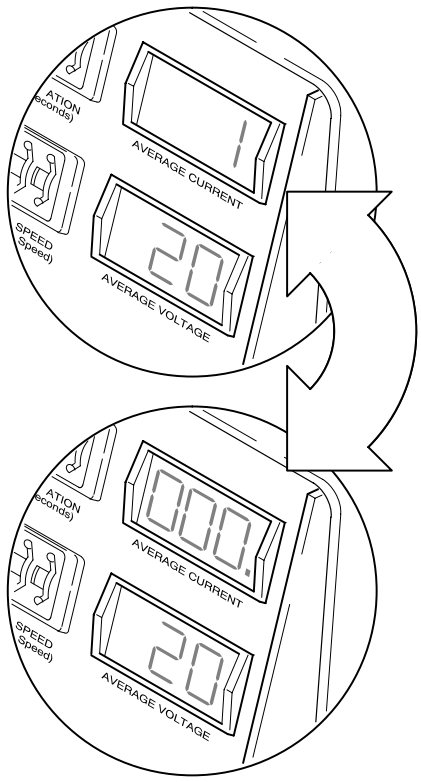


Figure 3-14 Data Display for Values Above 999

Exiting Program Mode

Caution!

Return the rotary switch settings to normal welding values after exiting program mode.

Exit the program mode by pressing **STOP/RESET**.

The system returns to operational mode. See **Caution**.

Test Mode

The power supply can be switched from the program mode to the test mode. When selected, the test mode is used to test the front panel controls, displays, and the optional remote operator pendant.

Table 3-6 Test Mode Code Numbers

Code No.	Description	Programmable
97	Test switches/pushbuttons	n/a
98	Test indicator lights/displays	n/a

Test Descriptions

97 to 98 *Front panel tests*

Code 97 is the front panel switch test code. Use this test to verify the operation of all front panel rotary switches and pushbuttons.

Code 98 is the front panel light test. Use this test to verify all front panel status indicator lights and LED displays.

Entering Test Mode

Refer to Figure 3-15. Enter the test mode using the following steps:

1. Press and hold **DOWNSLOPE**.
2. Press **ROTOR JOG** and then release both buttons at the same time.

   The SWS is now in program mode.
3. Enter 97 into **ROTOR SPEED**.

   Code 97 tests front panel switches and pushbuttons.
4. Press **ROTOR JOG**.

   The controller changes from the program mode to the test mode.

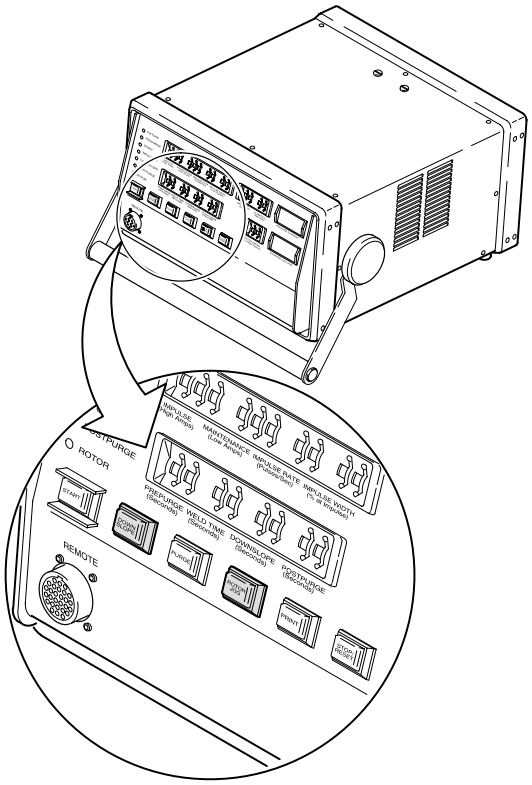


Figure 3-15 Entering Test Mode

Testing Rotary Switches

Review the rotary switch numbers. See Figure 3-1 on page 3-2. Switch one is Impulse, and switch two is Maintenance, etc.

Test code 97 displays the first switch that has a non-zero value. When the power supply is switched to the test mode, the digital displays indicate the value keyed into **IMPULSE**.

For example, if **IMPULSE** is set to 45.0, the display appears as shown in Figure 3-16. **Average Voltage** shows that switch one (Impulse) is being tested and **Average Current** shows its present setting of 45.0.

At this point **IMPULSE** can be rotated, and the numerical values of each switch position are displayed in **Average Current**. This exercise shows that the switches are working properly.

Once the operation of **IMPULSE** is verified, the switch must be set to zero to allow the diagnostic to look to the next switch.

With **IMPULSE** set to 0, the unit displays the values in switch two, **MAINTENANCE**. Use the same method described earlier to verify the operation of this switch.

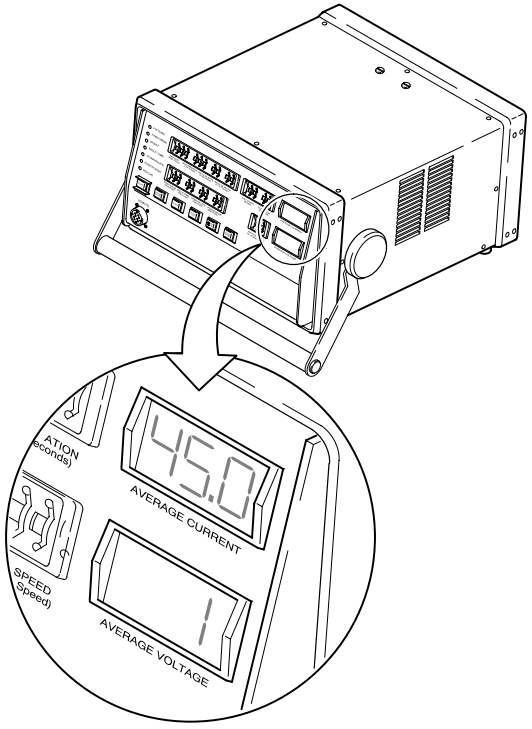


Figure 3-16 LED Test Display

After verification of **MAINTENANCE**, set its value to zero and move to switch three, and so on.

If a switch displays an incorrect value, it may be damaged or defective. Contact your Swagelok representative for service.

Testing Pushbuttons and Status Indicator Lights

Note: *The remote pendant is an optional feature. See Appendix B,* Optional Equipment, *for more information.*

In Test code 97, the pushbuttons and status indicator lights can also be functionally tested on both the front panel of the power supply and on the remote pendant.

When the pushbuttons are pressed, a specific status indicator light turns on. Pressing a pushbutton and seeing an indicator light turn on checks both for proper operation. The pushbuttons and corresponding status indicator lights are shown in Table 3-7.

Table 3-7 Pushbutton Test Reference

Pushbutton	Lights Illuminated
Start	Fixture and Rotor
Downslope	Prepurge
Purge	Start
Rotor Jog	Weld Time
Print	Downslope
Stop/Reset	Postpurge

Note: *The postpurge and rotor indicator lights are not tested on the remote pendant.*

The remote pendant pushbuttons and status indicator lights can also be tested. Plug in the remote pendant and follow the same procedure as before. Note that the **PRINT** pushbutton is not on the remote pendant. When testing the remote pendant pushbuttons, the status indicator light that turns on may not be adjacent to the pushbutton. The order is established by the button positions on the power supply front panel. See Table 3-7 for all pushbutton/indicator light pairings.

Testing Front Panel Lights/Displays

The tests executed in Test code 97 assume that the front panel status indicator lights and LED displays are functional. If you are in doubt, Test code 98 tests the lights and displays.

1. Exit Test code 97 by pressing **DOWNSLOPE** and **STOP/RESET** simultaneously, then release both pushbuttons.

2. Enter 98 into **ROTOR SPEED**.

   Test code 98 verifies the front panel lights and displays. All front panel status indicator lights and all segments of the LED displays are turned on.

Exiting Test Mode

1. To return to the program mode, press **DOWNSLOPE** and **STOP/RESET** simultaneously.

   After releasing the pushbuttons, the system will return to program mode.

2. Press **STOP/RESET** to exit program mode and return to operational mode.

Installing the Electrode in the Series 5/10/20 Weld Head

Each Swagelok weld head comes with a selection of electrodes. The following instructions show how to properly install the electrode in the Series 5/10/20 weld head. See Section 4, *Micro Weld Head,* for the micro weld head instructions.

Selecting the Proper Electrode

Electrode length and diameter depend on your weld head model and the outside diameter of the work piece being welded. To select the correct electrode, use the Electrode Selection Table in Appendix C, *Electrode Selection Tables and Geometry,* of this manual, or the appropriate weld procedure guideline.

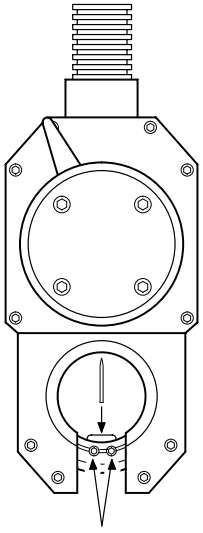


Figure 3-17 Electrode Installation

WARNING!

TURN THE CIRCUIT BREAKER OFF WHILE INSTALLING THE ELECTRODE.

Caution!

Do not jog or move the rotor unless the electrode is clamped in place.

Inserting the Electrode into a Rotor

1. Press **STOP/RESET.**

   The rotor makes one half of a revolution (180°) for the Series 5, 10, and 20 weld head, assuming that the weld head is not attached to a fixture block.

2. Verify that the rotor is in the correct position to install the electrode. See Figure 3-17. If the rotor position is not as shown, press **STOP/RESET** again.

   The micro weld head setup is different. The procedures are covered in Section 4, *Micro Weld Head*.

3. On the rear panel, turn off the circuit breaker.

4. Loosen the two electrode clamping screws. If you are replacing the electrode, remove the electrode.

5. Insert the new electrode with the sharp tip pointing out. Tighten the electrode clamping screws slightly to temporarily hold in place.

Setting the Arc Gap

The proper arc gap setting facilitates control of the weld and improves consistency. The following steps cover how to set the arc gap.

The arc gap is set by using the arc gap gage provided with the weld head. The gage is adjusted for the desired arc gap and then installed in the rotor aperture. With the gage in place, the electrode can be positioned with reasonable accuracy.

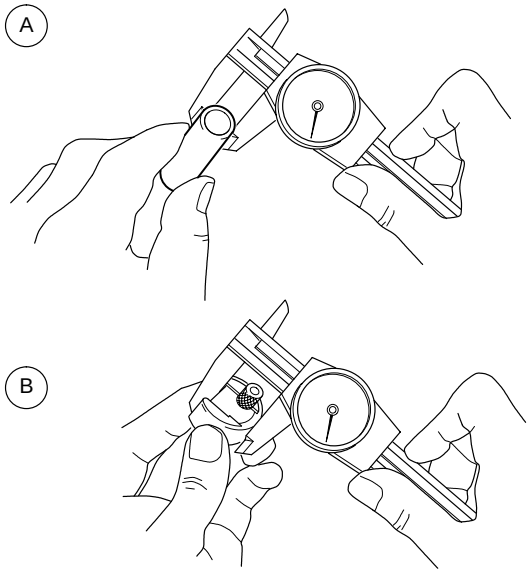


Figure 3-18 Setting the Arc Gap gage

Setting the Arc Gap Gage

1. Measure the outside diameters of the work pieces being welded using a caliper or micrometer. See Figure 3-18(A).
2. Refer to the tables for your weld head model in Appendix E, *Arc Gap Gage Setting Tables*. Find the "actual" outside diameter nearest to your measurement.
3. Adjust the arc gap gage to match the setting from the table or weld procedure guideline. See Figure 3-18(B).
4. To calculate arc gap gage settings for other arc gaps, see the arc gap gage setting formula in Appendix E, *Arc Gap Gage Setting Tables*.
5. Gage settings for Swagelok ATW fittings are in the tables in Appendix E, *Arc Gap Gage Setting Tables*.

Setting the Arc Gap

1. Insert the arc gap gage into the rotor. See Figure 3-19(A).
2. Tilt the weld head upward. Loosen the electrode screw allowing the electrode to drop onto the gage surface. See Figure 3-19(B).
3. Tighten the electrode clamping screws just enough to secure the electrode. Remove the arc gap gage.

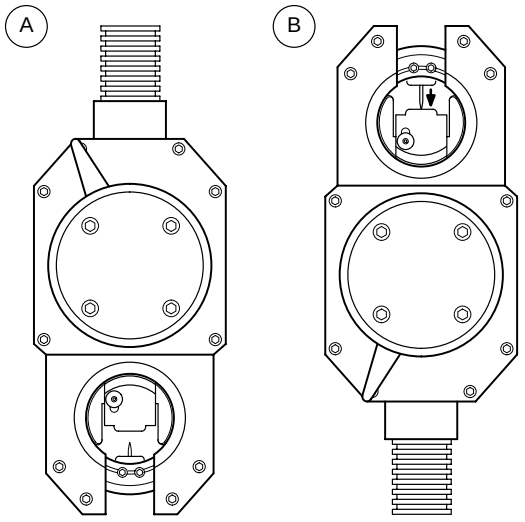


Figure 3-19 Setting the Arc Gap

Caution!

Do not jog or move the rotor unless the electrode is clamped in place.

4. Restore power to the SWS by turning the circuit breaker on.
5. Press **STOP/RESET** to return the rotor to the home position and visually inspect the rotor smooth rotation.

Preparing the Work

Refer to Figure 3-20. Prepare the tube pieces to be welded.

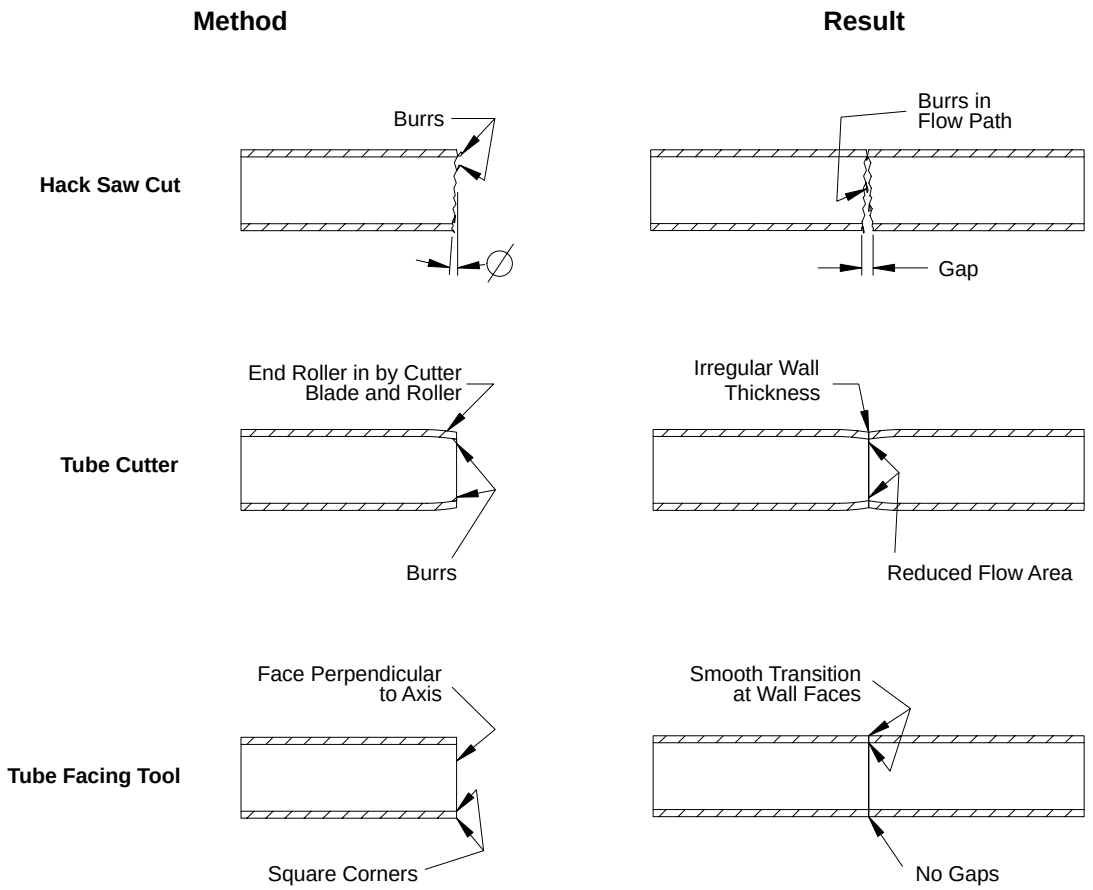


Figure 3-20 Tube Preparation

Tubing must be square and burr-free to ensure repeatable, high-quality autogenous fusion welds. Cut the tubing to length with a hacksaw or tube cutter. Face the tube ends with a lathe or a portable facing tool. Deburr the ends, making sure that both the inside and outside diameters are square and burr-free. Clean the tube ends using an appropriate solvent.

Minimize the chance of a poor quality weld by following these guidelines:

- Tube ends must be square.
- Tube ends must be burr-free.
- Tube ends must not have a wall thickness variation exceeding ±15 % of nominal.
- Tube ends must be free of any rust, grease, oil, paint, or other surface contaminates.

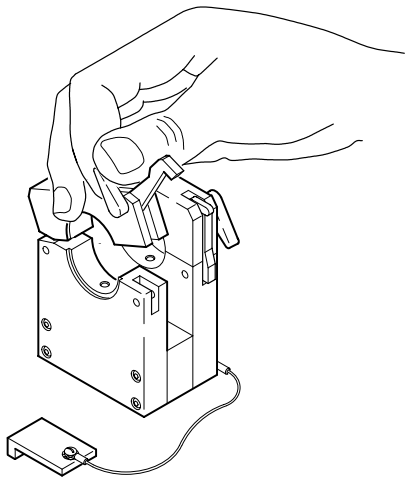


Figure 3-21 Opening the Fixture Block

Fixturing the Work

Select or configure the appropriate fixture block. Select the collets to match the work outside diameter.

Selecting the Fixture Block and Collets

1. Select the fixture block that accepts the outside diameter of the tube to be welded. See Table 1-6 in Section 1, *Introduction*.
2. Select the proper collets for the diameter of the parts being welded. See Table 1-8 in Section 1, *Introduction*.

Installing the Collets in a Tube Fixture Block

1. Release both levers and open the tube fixture block. See Figure 3-21.
2. Install the collet halves in both the top and bottom side plates and tighten the collet screws. Make sure the collet shoulder is flush against the fixture side plate. See Figure 3-22.

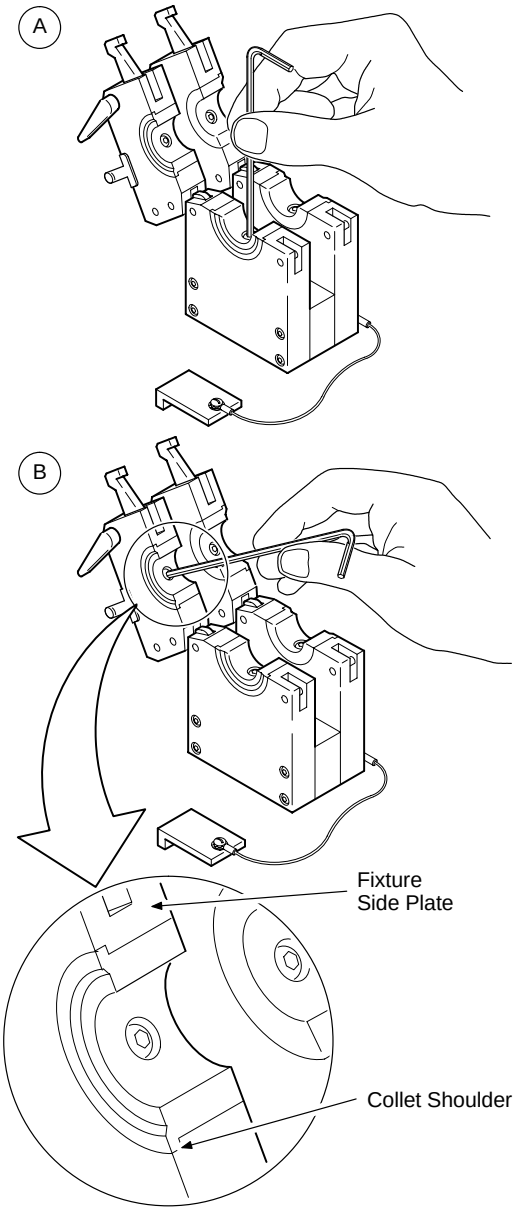


Figure 3-22 Installing Collets

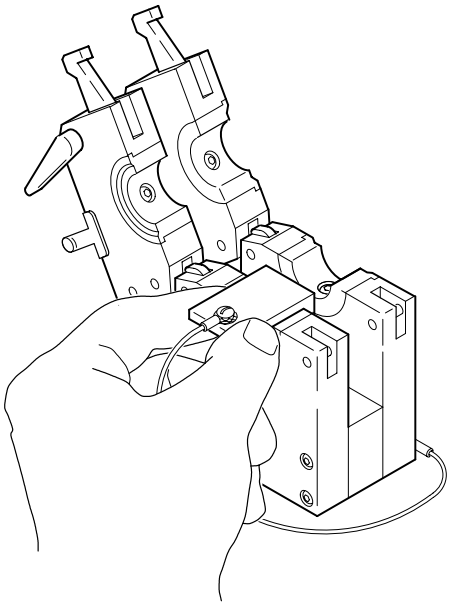


Figure 3-23 Place the Centering Gage

Aligning the Work Pieces in the Tube Fixture Block

1. Place the centering gage in one side of the tube fixture block. The centering gage must span the width of the collet. See Figure 3-23.
2. Butt one work piece against the centering gage. See Figure 3-24(A).
3. Lock down the top side plate. See Figure 3-24(B).
4. Remove the centering gage.

Note: *When welding a Swagelok ATW fitting to tubing, butt the tubing against the centering gage first.*

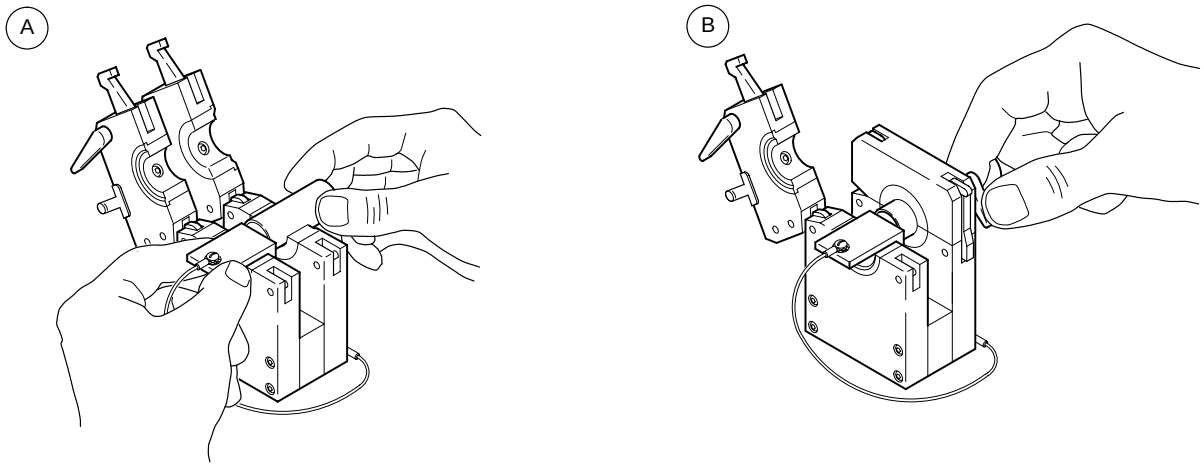


Figure 3-24 Placing First Work Piece in the Fixture Block

5. Butt the second work piece against the first work piece, and lock down the top side plate. See Figure 3-25.

6. Inspect 360° around the weld joint for fit and alignment. If the alignment is not correct, proceed to the Appendix H, *Fixture Block Alignment*.

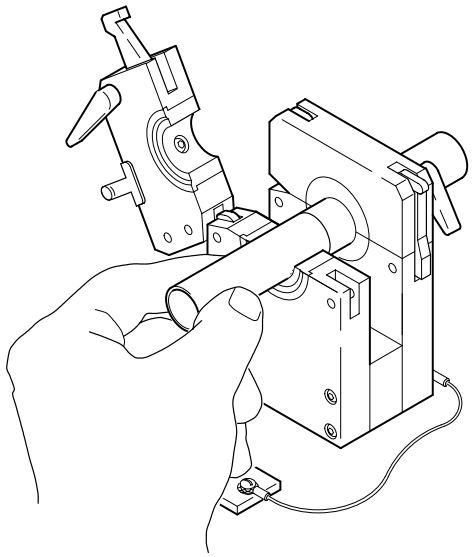


Figure 3-25 Placing Second Work Piece

Connecting the Purge Gas Line

Refer to Figure 2-6 in Section 2, *Installation*. Connect the internal purge gas line to the work pieces.

1. Set the internal purge gas flow meter depending on the inside diameter of the work pieces. See Appendix G, *Gas Flow Rate Tables*.

2. Open the shut-off valve in the purge gas line.

   The length of time for internal purge before welding depends on the internal volume and length of the work piece to be welded.

Connecting the Weld Head to the Fixture Block

The instructions that follow refer to a Series 5/10/20 style weld head. See Section 4, *Micro Weld Head*, for instructions for using a micro weld head.

Safety Interlock

This feature disables the power supply when the weld head is not attached to the fixture block. On the front panel, **Fixture** remains on until the weld head is properly attached.

Note: *Use only safety interlock weld heads with the D100 power supply.*

A sensor in the weld head signals the power supply when the fixture block is connected. **Fixture** turns off and the power supply is ready to weld.

The safety interlock feature is not included on all weld heads. Table 3-8 lists the first serial number of each weld head model that includes the safety interlock feature.

Table 3-8 Weld Heads with Safety Interlock

Model No.	Serial No.
CWS-M-MTR-A	10212 or higher
CWS-4MRH-A	20090 or higher
CWS-4MFH-A	30045 or higher
CWS-8MRH	all
CWS-5H-B	60100 or higher
CWS-10H-A	70033 or higher
CWS-20H-A	80015 or higher
SWS-20H-B	all

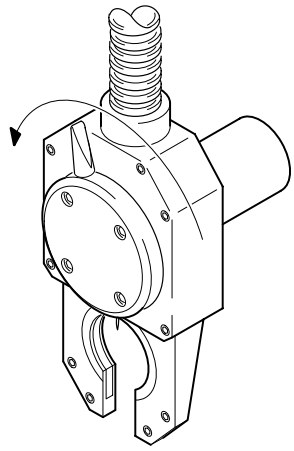


Figure 3-26 Releasing the Locking Lever

Mating the Weld Head to the Fixture Block

1. Rotate the locking lever on the weld head counter-clockwise until it stops. See Figure 3-26.
2. Insert the weld head into the fixture block. See Figure 3-27(A).
3. Rotate the locking lever clockwise to secure the weld head. See Figure 3-27(B).
4. Examine the **Fixture** light. Verify that it is off.

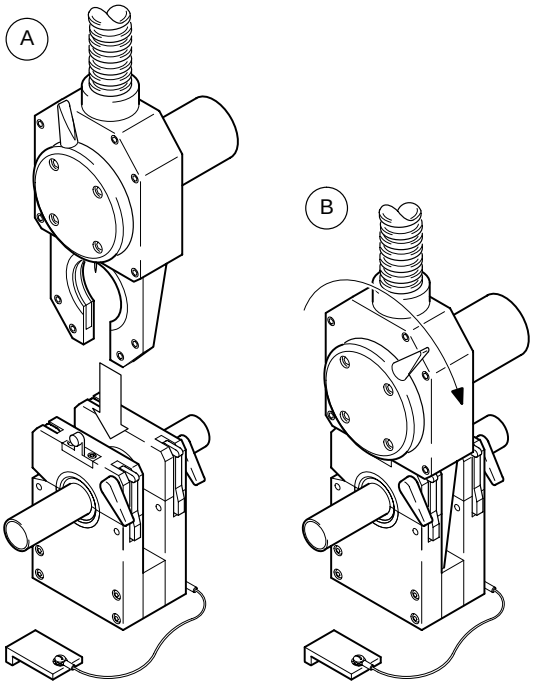


Figure 3-27 Mating the Weld Head to the Fixture Block

Entering the Weld Parameters

The following describes the parameters that are set on the SWS front panel as well as briefly discussing how the parameters are determined.

Using a Weld Procedure Guideline

There are several reference weld procedure guidelines included in Appendix I, *Weld Procedure Guidelines,* of this manual. If assistance is needed in obtaining more Weld Procedure Guidelines, please provide your Swagelok representative with your specific requirements.

The weld procedure guideline listed in Table 3-9 is based on 1/2 in. tubing with a 0.049 in. wall thickness.

Table 3-9 Sample Weld Procedure Guideline

Weld Parameter	Setting
Impulse	58.8
Maintenance	17.6
Impulse Rate	10
Impulse Width	35
Arc Start	32
Duration	0.5
Prepurge	10
Weld Time (2 revolutions)	36
Downslope	18
Postpurge	20
Rotor Speed	26

Using the weld procedure guideline in Table 3-9, enter the listed values on the front panel rotary switches. Once this is done, the digital display windows should read a zero with a flashing decimal point. The unit is ready for operation.

Note: *If the displays do not read zero, please refer to "Operational Mode" on page 3-12.*

Effects of Weld Parameters

The following text briefly discusses how the weld parameters relate to the current waveform and the effects of any parameter changes.

Weld Parameters Affect the Output Waveform

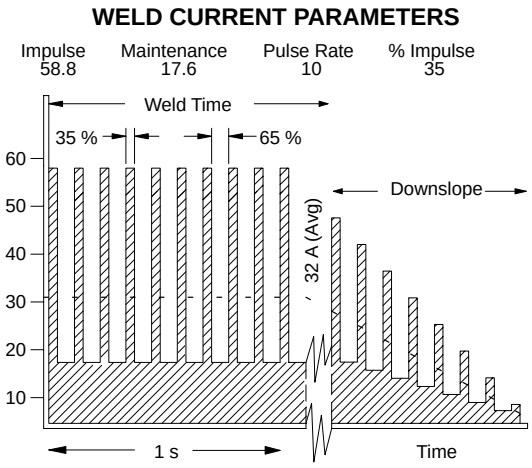


Figure 3-28 Weld Current Waveform

The shape and duration of the output current waveform created during the weld cycle is determined by the weld parameter settings entered on the SWS front panel. The values from the weld procedure guideline in Table 3-9 create a current waveform as shown in Figure 3-28.

During a typical weld, the power supply pulses between high amp current and low amp current. In the example shown at the right, the current control settings are:

- **IMPULSE** 58.8 A
- **MAINTENANCE** 17.6 A
- **IMPULSE RATE** 10 pulses per second
- **IMPULSE WIDTH** 35 %

In this case, the current pulses between the high and the low levels 10 times per second. The current is at the high level 35 % of the time and at the low level 65 % of the time.

Effects of Weld Parameter Changes

Impulse and Rotor Speed affect the depth of penetration of the weld.

Impulse Width also affects weld penetration. The control allows fine tuning of the weld penetration level.

Pulse rate is typically set so that each weld spot overlaps the previous one by at least 60 %.

Setting the Shield Gas Flow

1. Verify the shielding and purge gas connections to the work pieces.
2. Set the shielding gas flow meter to the proper setting. Refer to Table 3-10.
3. Press **PURGE** to operate the shielding gas solenoid valve and to start the shielding gas flow. Allow the system to purge for several minutes on initial setup to clear the shielding gas system of oxygen.
4. Press **PURGE** again to close the shield gas solenoid valve.

Caution!

Excessive or insufficient flow rates may affect arc start and arc stability.

Table 3-10 Shield Gas Flow Rates (Argon)

Weld Head Series	std ft^3/h (L/min)
5	10 to 15 (4.7 to 7.1)
10	10 to 20 (4.7 to 9.4) *
20-A	10 to 20 (4.7 to 9.4) *
20-B	20 to 40 (9.4 to 18.8) *

*Set the flow to the higher rates when welding at high current levels.

Starting and Completing the Weld

1. Check the following before starting the weld:
   - All rear panel connections are complete.
   - Shielding and purge gas lines are properly connected.
   - The inert gas source is on.
   - Correct gas flow rates are set.
   - Weld pieces are properly aligned and clamped in the fixture block.
   - The proper arc gap is set.
   - The weld head is connected to the fixture block.
   - The proper weld procedure guideline settings have been entered.
   - All status indicator lights are off.
   - The internal purge gas is flowing.

Note: *Although the power supply welds in any orientation, it is recommended that it be placed in the upright position before welding.*

WARNING!

Do not touch the cable connectors during arc start. If the cables have been damaged, a potential for electric shock exists.

2. Press **START.**

   Total time for the process is the sum of the following times:

   - prepurge
   - duration (negligible)
   - weld time
   - downslope
   - postpurge

   In the example given in Table 3-9, the total process would be 84.5 seconds.

Note: *If the arc fails to start, the power supply enters the idle state. See Section 7,* Troubleshooting, *for possible causes and corrective actions.*

Display Indications During Welding

During welding, the status indicator lights on the front panel light in the following sequence:

- **Prepurge**
- **Start**
- **Weld Time** and **Rotor***
- **Downslope**
- **Postpurge**

  ***Rotor** remains on during **Weld Time** and **Downslope**, and until the rotor returns to the home position after welding.

Average Current LED Display

Compare the value shown on the display with the average current value listed under Arc Start on the weld procedure guideline. The Arc Start value is calculated during the development of the guideline. The value displayed during welding is generally within 10 % of the calculated value.

Average Voltage LED Display

The value displayed during weld time is typically between 5 V and 15 V. The display may be used to monitor voltage fluctuations that can result from

- electrode wear
- out-of-round tubing
- contamination of shielding gas.

After the Weld is Complete

1. Wait for all status indicator lights to go off.
2. Check if the fixture block has cooled enough to be safely handled. Allow additional cooling time if necessary before handling. If necessary, increase postpurge time to aid cooling.
3. Release the locking lever on the weld head housing.
4. Remove the weld head from the fixture block.

   If it is difficult to remove the weld head, release one of the side plate lever cams.
5. Remove the internal purge gas lines from the welded assembly.
6. Release the levers on the fixture block.
7. Open the side plates of the fixture block.
8. Remove the welded assembly.

WARNING!

USE GLOVES OR OTHER PROTECTIVE DEVICES IF YOU MUST HANDLE PARTS IMMEDIATELY AFTER WELDING. THE PARTS CAN BE EXTREMELY HOT AND MAY CAUSE BURNS.

Caution!

Do not immerse the hot fixture block in water after welding. If using only one fixture block, allow it to cool before performing the next weld. More than one fixture block can be used for repetitive welding.

Note: *Inspect and clean the electrode after each weld. Look for oxidation, wear, or weld material on the tip.*

Operation Summary

1. Install the electrode.
2. Set the arc gap using the arc gap gage.
3. Prepare the work pieces.
4. Select the correct fixture block and collets.
5. Install the collets in the fixture block.
6. Align the work pieces in the fixture block.
7. Connect the internal purge gas line to the work piece to be welded, and set the flow meter.
8. Press **PURGE**, and set the shield gas flow.
9. Press **PURGE** to stop the shielding gas flow prior to starting the weld.
10. Connect the weld head to the fixture block.
11. Program the welder.
12. Press **START** and complete the weld.
13. Remove the weld head from the tube fixture block.
14. Remove the welded assembly from the tube fixture block.

Section 4
Micro Weld Heads

CWS-4MRH-A, CWS-4MFH-A, CWS-8MRH

Introduction

The micro weld heads are used to weld work pieces from 1/16 in. to 1/2 in. (3 mm to 12 mm) OD. The Series 4 Micro Weld Head can weld work pieces from 1/16 in. to 1/4 in. (3 mm to 6 mm) OD and is available in both rigid-drive and flexible-drive configurations. The Series 8 Micro Weld Head can weld work pieces from 1/4 in. to 1/2 in. (6 mm to 12 mm) OD and is available in a rigid-drive configuration. All micro weld heads operate with a detachable motor module. See Figure 4-1.

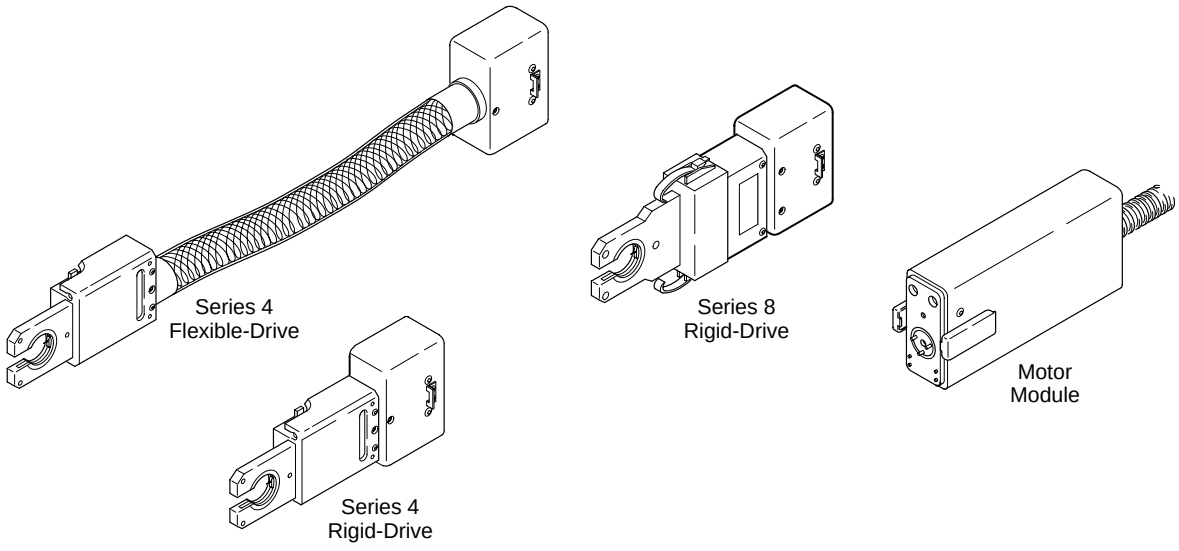


Figure 4-1 Rigid-Drive and Flexible-Drive Micro Weld Heads

This section presents information that is specific to the micro weld head assembly. Additional handling is necessary because the motor module and weld head are separate units. The micro weld head fixtures do not use separate collets, so fixture setup differs slightly from the Series 5/10/20 fixture block procedures.

The procedures, unless noted, are the same for all micro weld heads. Most figures in this section show the Series 4 Rigid-Drive Micro Weld Head.

Topics common to all weld heads are not covered in this section. See Sections 2, 3, and 5 for information on power supply setup and weld procedure guidelines.

The section includes

- micro fixture tool
- installing the motor module
- installing the micro weld head
- installing/replacing the electrode
- setting the arc gap
- fixturing the work
- connecting the micro weld head to the fixture
- considerations during welding
- using the optional bench mounting bracket.

Using the Micro Fixture Tool

Each micro weld head includes a micro fixture tool. See Figure 4-2. The primary purpose of the tool is to latch and unlatch the fixtures. In addition, the tool can be used for the following:

- aligning the micro weld head rotor
- attaching the optional bench mount bracket (Series 8 only)

The micro fixture tool has a hole that allows the tool to be secured by a key chain.

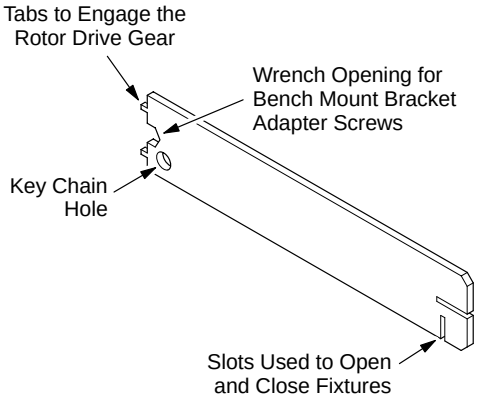


Figure 4-2 Micro Fixture Tool

Installing the Motor Module

Connect the motor module to the power supply the same way as a Series 5/10/20 Weld Head.

1. Turn off the power supply circuit breaker on the rear panel. See Figure 4-3.
2. Connect the motor module to the power supply. See page 2-7 in Section 2, *Installation*, for instructions.
3. Turn on the power supply.
4. Press **STOP/RESET.**

   The motor moves the rotor drive gear to its home position.

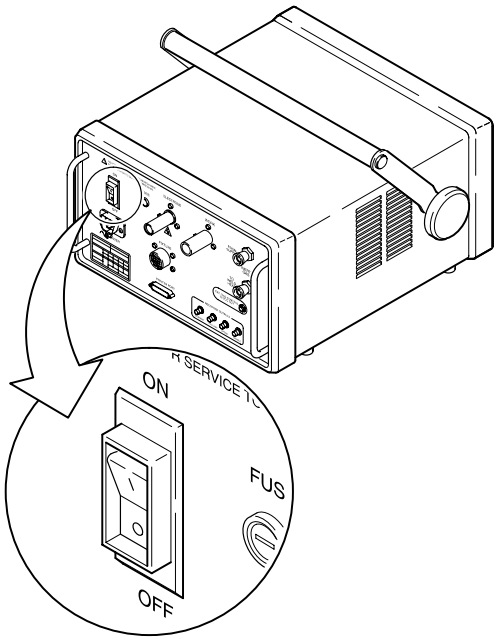


Figure 4-3 Power Supply Circuit Breaker

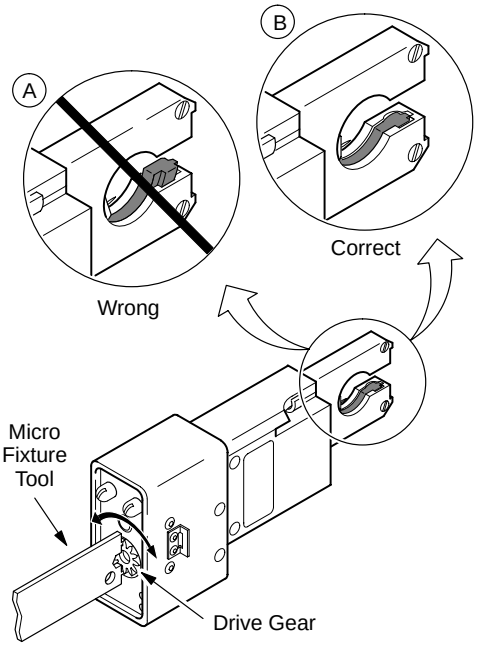


Figure 4-4 Rotor Manual Adjustment

Installing the Micro Weld Head

1. Using the micro fixture tool, turn the drive gear on the base of the micro weld head to align the rotor opening to the weld head housing opening. See Figure 4-4(A) and Figure 4-4(B), showing views of the rotor misaligned and in proper alignment.

   The drive gear on the base of the micro weld head must be aligned so that it meshes with the drive pins on the motor module housing.

2. Locate the shielding gas port on the micro weld head and verify that the O-ring is in place. See Figure 4-5.

   The O-ring seals the gas port. A valve in the port opens the gas flow through the motor module. The valve opens when the micro weld head is properly connected to the motor module.

3. Align the connecting surfaces of the micro weld head and motor module. See Figure 4-5.

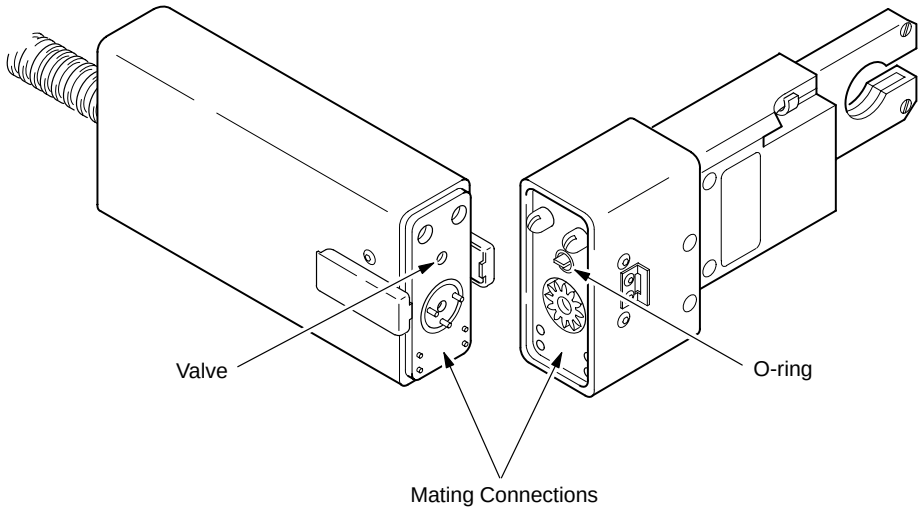


Figure 4-5 O-ring and Mating Connections

4. Push the micro weld head onto the motor module until it is firmly seated, then lock the assembly together with the two side latches. See Figure 4-6(A) and (B).

5. Press **STOP/RESET**.

   The rotor turns one revolution and stops at the home position. The opening in the rotor aligns to the opening in the micro weld head housing. If not, disconnect the weld head and repeat the procedure.

Caution!

Do not force the micro weld head and motor module together. The drive gears of the micro weld head and motor module must be aligned for the pieces to mate correctly. If you have problems mating the components, rotate the micro weld head drive gear a small amount and try again. Refer to step 1. on page 4-4.

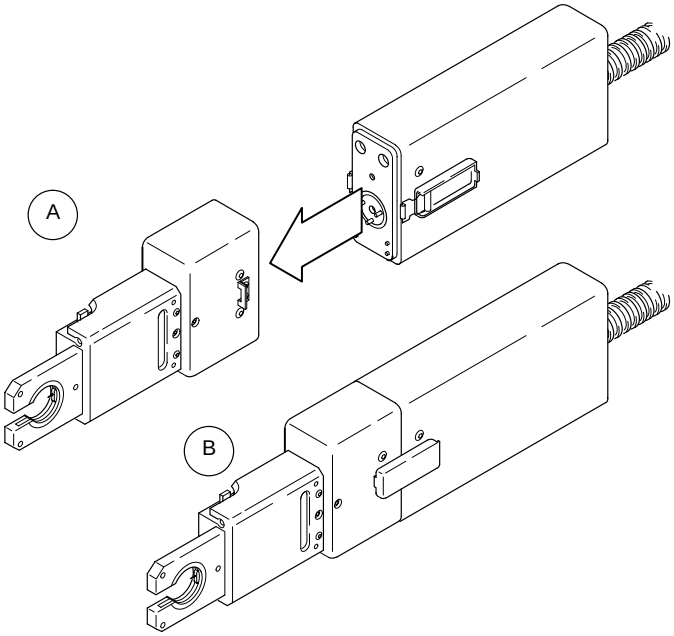


Figure 4-6 Connecting Weld Head and Motor Module

Installing/Replacing the Electrode

WARNING!

TURN OFF THE POWER SUPPLY BEFORE INSTALLING AN ELECTRODE!

Note: *Experience suggests replacement of the electrode when it shows signs of deterioration.*

The micro weld head accessory package includes a screwdriver, tweezers, and an electrode cleaning tool. Use these tools for installing or replacing the electrode.

1. Select the proper electrode for the job to be performed. See Appendix C, *Electrode Selection Tables and Geometry.*
2. Turn off the power supply circuit breaker on the rear panel. See Figure 4-3.
3. Disconnect the micro weld head from the motor module.
4. Manually turn the rotor drive gear, shown in Figure 4-4, until the electrode clamping screw is exposed. See Figure 4-7.

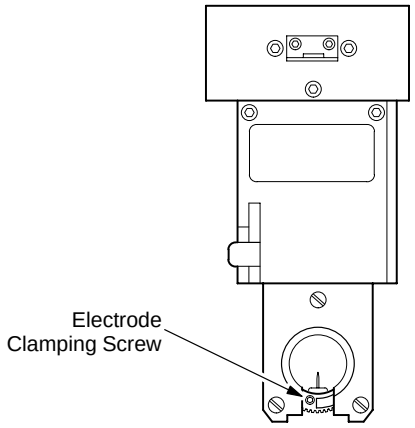


Figure 4-7 Electrode Clamping Screw Location

Caution!

Do not rotate the rotor with the electrode clamping screw loose. Damage to the micro weld head housing may result.

5. Loosen the electrode clamping screw holding the micro weld head as shown in Figure 4-8(A).

   This orientation helps to prevent the electrode from falling out during installation.

6. Install a new electrode with the tweezers to avoid contamination. Insert the electrode through the ceramic insulator and into the rotor to its full insertion depth. Make sure the sharp tip of the electrode is pointing out. See Figure 4-8(B).

7. Tighten the clamping screw sufficiently to prevent the electrode from falling out of the rotor. Do not overtighten the clamping screw.

8. Clean the electrode with the provided electrode cleaning tool.

   Push the electrode into the electrode cleaning tool and rotate back and forth two to three times.

Note: *Clean the electrode before every weld to ensure optimum performance.*

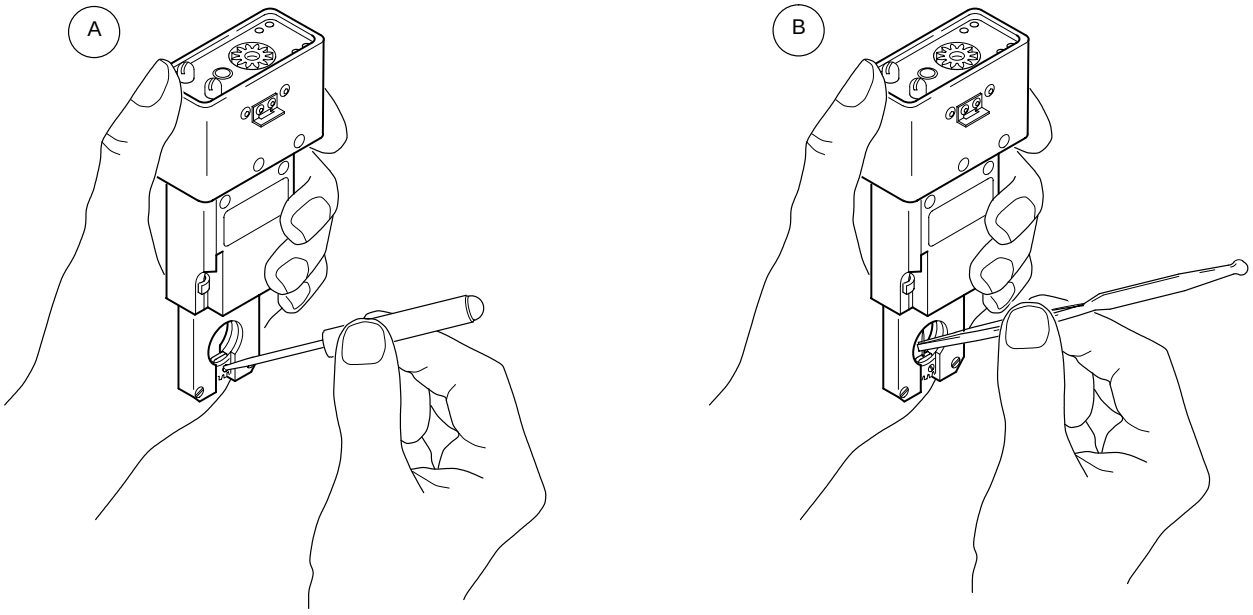


Figure 4-8 Installing the Electrode

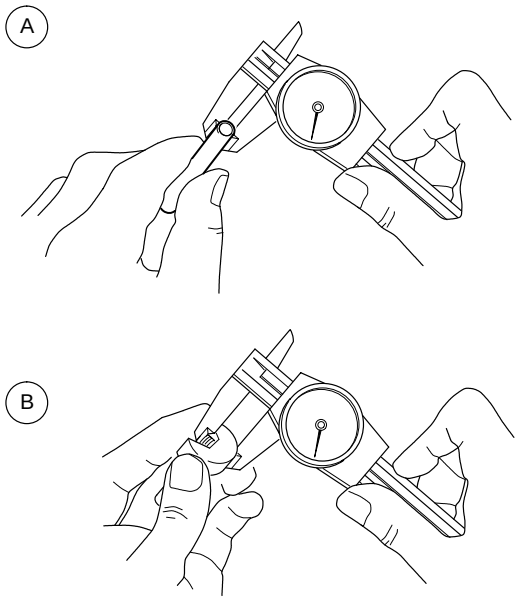


Figure 4-9 Setting Arc Gap Gage

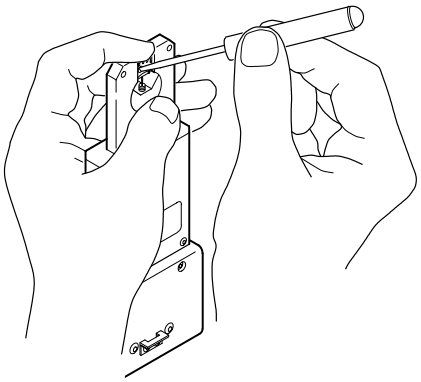


Figure 4-10 Setting the Arc Gap

Caution!

Make sure the electrode is secure, but do not overtighten. The electrode could be damaged as a result.

Setting the Arc Gap

The micro weld head accessory package also includes an arc gap gage. The gage is required to set the arc gap. The gage fits the rotor aperture and adjusts for the desired arc gap.

1. Measure the OD of the work to be welded with a caliper or micrometer and record the value. See Figure 4-9(A).
2. Refer to the CWS-4MRH-A/CWS-4MFH-A or CWS-8MRH tables in Appendix E, *Arc Gap Gage Setting Tables*. Find the “Actual OD” column.
3. Locate the OD value in the table that matches the OD of the work. Find the arc gap gage setting listed for that OD and record it.
4. Set the arc gap gage to the value from the table using the provided 3/32 in. hex wrench. Measure from the bottom of the arc gap gage to the top of the adjustment screw. See Figure 4-9(B).
5. Insert the arc gap gage into the micro weld head rotor opening.
6. Hold the micro weld head so that the electrode tip is pointing down. Loosen the electrode clamping screw to allow the electrode to fall against the arc gap gage. See Figure 4-10.
7. Tighten the electrode clamping screw to hold the electrode in place. Do not overtighten. Remove the arc gap gage.

   The rotor may move due to the torque of tightening the clamping screw. Use your finger to hold the rotor in place.
8. If the micro weld head is disconnected from the motor module, attach it to the motor module. Complete the steps in *Installing the Micro Weld Head,* beginning on page 4-4. When complete, return here.
9. Turn on the power supply.
10. Press **STOP/RESET**.

    The rotor starts moving and stops at the home position.

Fixturing the Work

The work pieces must be properly prepared before fixturing. See page 3-28 in Section 3, *Operation*, for information.

1. Locate the centering gage. Turn the gage so the labeled side is face up. Insert the gage into the fixture. See Figure 4-11.

   The orientation of the fixture does not matter.

2. Open the fixture side facing the labeled side of the centering gage by rotating the latch 90°. See Figure 4-12.

   The fixture opens with a scissors type action. Figure 4-12 shows how to use the micro fixture tool on both the Series 4 and Series 8 fixtures.

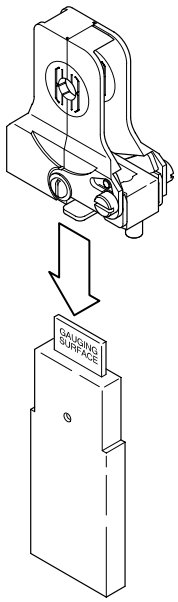
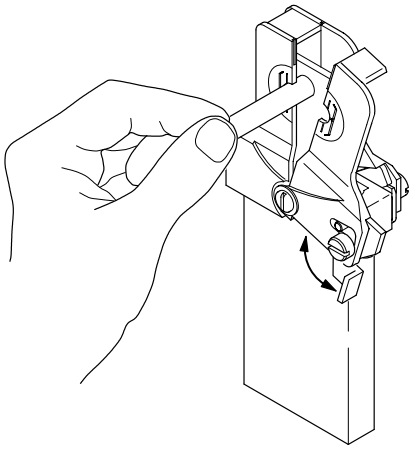
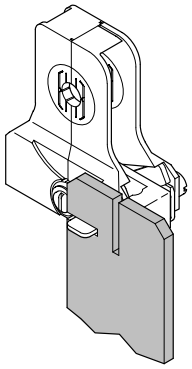
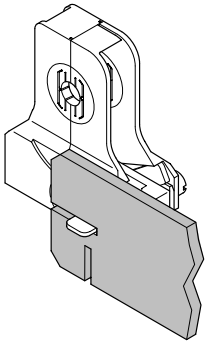


Figure 4-11 Inserting Centering Gage



Opening the Fixture





Note: Use the micro fixture tool for Series 4 and Series 8 fixtures

Figure 4-12 Insert First Work Piece

Caution!

When closing the fixture, be sure the moving side of the fixture engages into the small groove on the stationary side of the fixture.

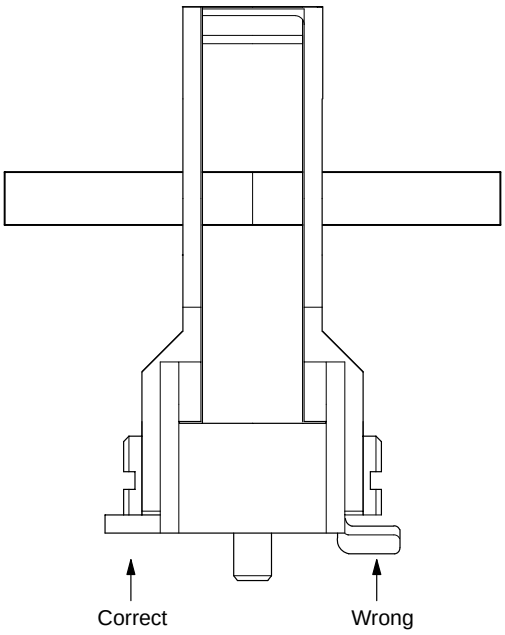


Figure 4-13 Checking the Weld Joint (Series 4 Fixture)

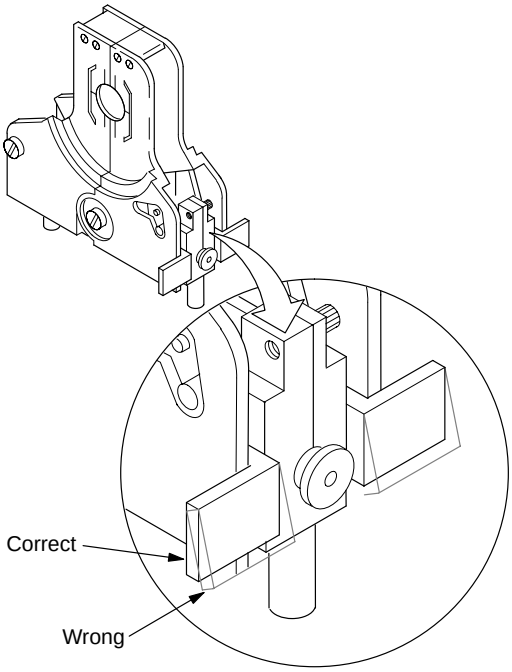


Figure 4-14 Proper Latch Position (Series 8 Fixture)

3. Insert the first work piece, butting the weld end against the gage surface. Close and latch that side of the fixture. Make sure that the latch is fully closed against the body of the fixture. See Figure 4-13.

4. Remove the centering gage.

5. Open the other side of the fixture and insert the second work piece. Butt the weld ends together. Close and latch that side.

6. Check the weld joint for proper fit and alignment. See Figure 4-13. Verify that the latches are fully closed. See Figure 4-13 (Series 4) or Figure 4-14 (Series 8).

7. Connect the purge gas line to the work pieces. See Figure 2-6 in Section 2, *Installation*.

8. Open the shut-off valve in the purge gas line.

9. Set the flow meters according to the weld procedure guideline for both the shielding and internal purge gas.

Table 4-1 Shield Gas Flow Rates (Argon)

Weld Head Series	std ft^3/h (L/min)
4MH	8 to 10 (4 to 4.7)
8MH	15 to 20 (7.1 to 9.4)

The length of time for internal purge before welding depends on the internal volume and length of the work piece to be welded. See Appendix G, *Gas Flow Rate Tables*.

Connecting the Micro Weld Head to the Fixture

1. Place the fixture on the micro weld head.

   - On the Series 4 Micro Weld Head, make sure the fixture is firmly seated. Rotate the locking lever 90° to secure the fixture to the micro weld head. See Figure 4-15(A).
   - On the Series 8 Micro Weld Head, engage the two latch springs over the button keepers on the sides of the fixture and close the latch levers. See Figure 4-15(B).

   The micro weld head assembly and the work are ready for welding.

2. Press **PURGE** to begin the shielding gas flow. The shielding gas should remain on at all times when using the micro weld head.

3. Program the power supply and perform the weld using the procedures established in Section 3, *Operation*.

Caution!

Make sure the fixture latches are closed before attaching the fixture to the micro weld head. The electrode can be damaged if the latches are left open during welding.

Caution!

Make sure that the purge line or a heavy work piece does not exert a side load force on the fixture. This may cause an unacceptable weld, damage to the micro weld head, or both.

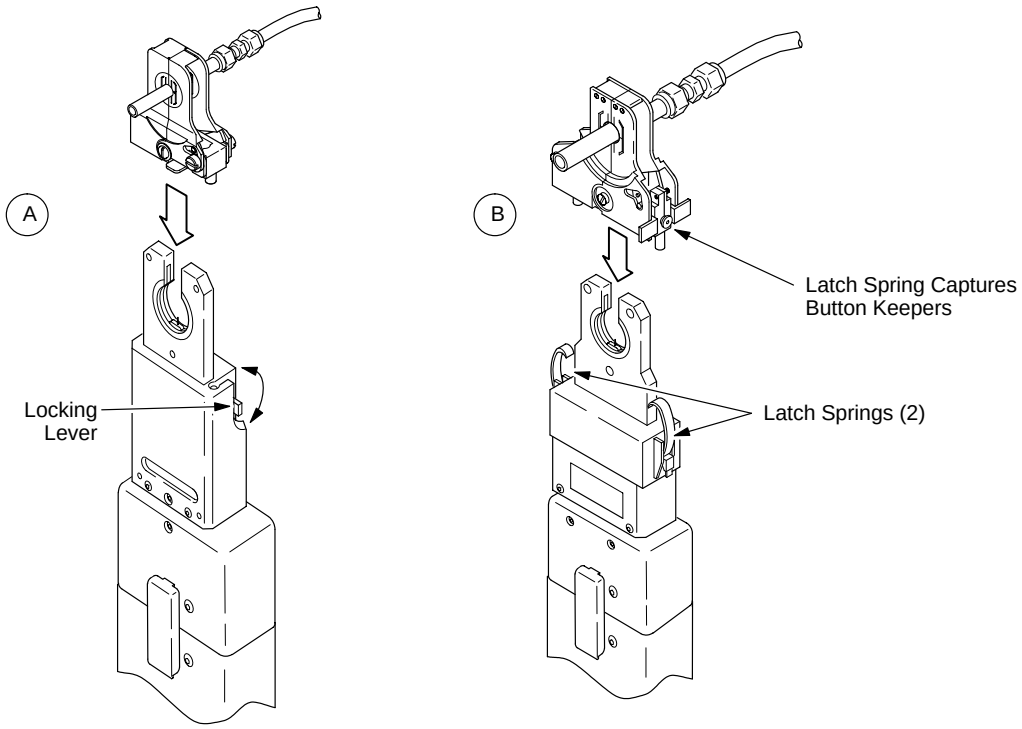


Figure 4-15 Placing the Fixture on the Micro Weld Head

Considerations During Welding

The approach to welding using the micro weld head is similar to that used for other Swagelok weld heads. Develop a weld procedure guideline as you would for any job. The power supply controls and indicators work the same. However, the unique qualities of the micro weld head and its fixtures cause some noticeable differences during welding:

- The sound of the weld is slightly louder compared to other Swagelok weld heads. This is due to the reduced size of the fixture.
- You may notice a clicking sound during the downslope cycle. This is normal. The fixture contracts slightly due to heat dissipation, producing the sound.
- Because the fixture is small, heat build-up may make the device too hot to handle immediately after welding. Hold the fixture in the base areas shown in Figure 4-16. Use the optional aluminum cooling plate to hold the fixture and allow it to cool faster. See Figure 4-16.
- Extended internal purging assists the cooling process.

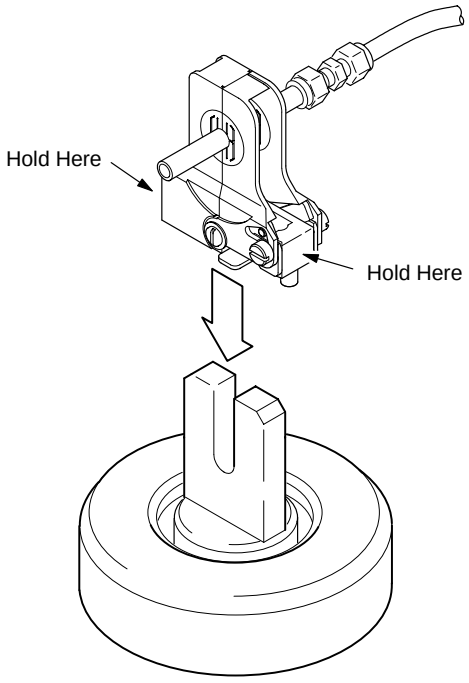


Figure 4-16 Cooling Plate

WARNING!

THE FIXTURE MAY BE HOT AFTER WELDING IS COMPLETE. USE CAUTION WHEN HANDLING.

Using the Optional Bench Mounting Bracket

Caution!

Do not put the micro weld head in a vise. Severe damage may result, which would void any warranty.

The bench mounting brackets attach Series 4 and Series 8 Micro Weld Heads to a workbench. There are two mounting plates on the bracket, giving you a choice of mounting orientations.

Series 4 Bench Mount Bracket

1. Determine the mounting orientation of the bracket on the workbench. See Figure 4-17. Secure the bracket to the workbench. Make sure the latch is accessible.
2. Open the latch on the side of the bracket.
3. Slide the micro weld head into the bracket from below until the raised detent on the bracket is aligned to the machined recess of the micro weld head body. Fasten the latch to secure the micro weld head to the bracket.

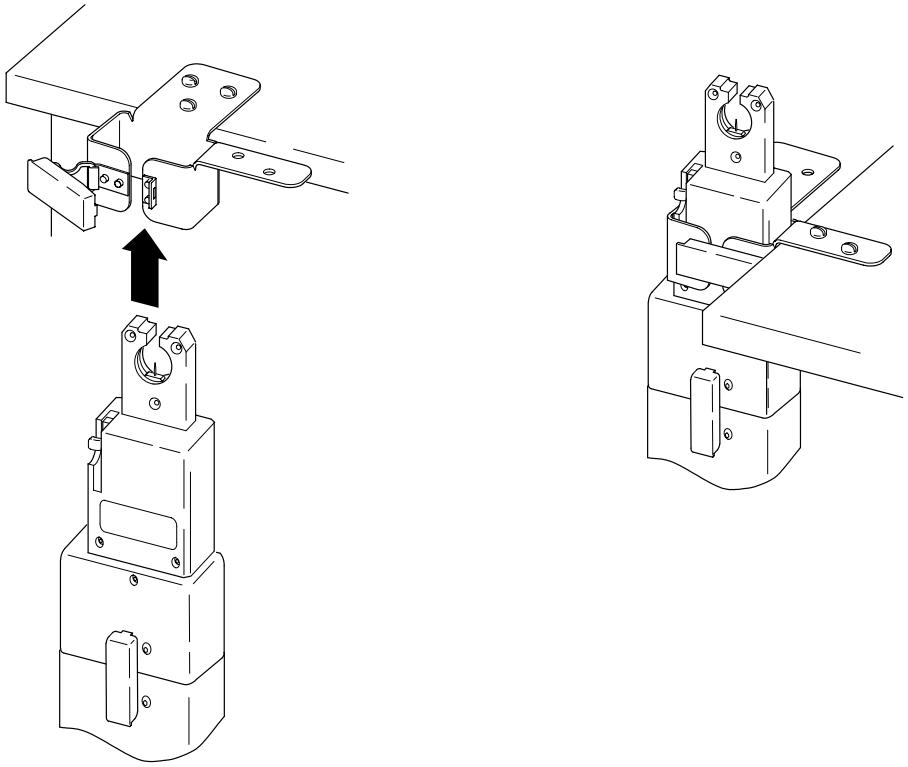


Figure 4-17 Using the Series 4 Mount Bracket

Series 8 Bench Mount Bracket

1. Remove one of the button head screws holding the latch bracket to the weld head. See Figure 4-18(A). Insert one of the supplied adapter screws.

2. Secure the adapter screw with a 1/4 in. wrench or the micro fixture tool. See Figure 4-18(B).

3. Repeat steps 1. and 2. for the remaining latch bracket screw. Verify the latch bracket remains securely attached to the weld head.

4. Secure the bracket to any appropriate workbench.

5. Position the weld head so that the exposed ends of the adapter screws slide through the holes in the bracket. See Figure 4-18(C).

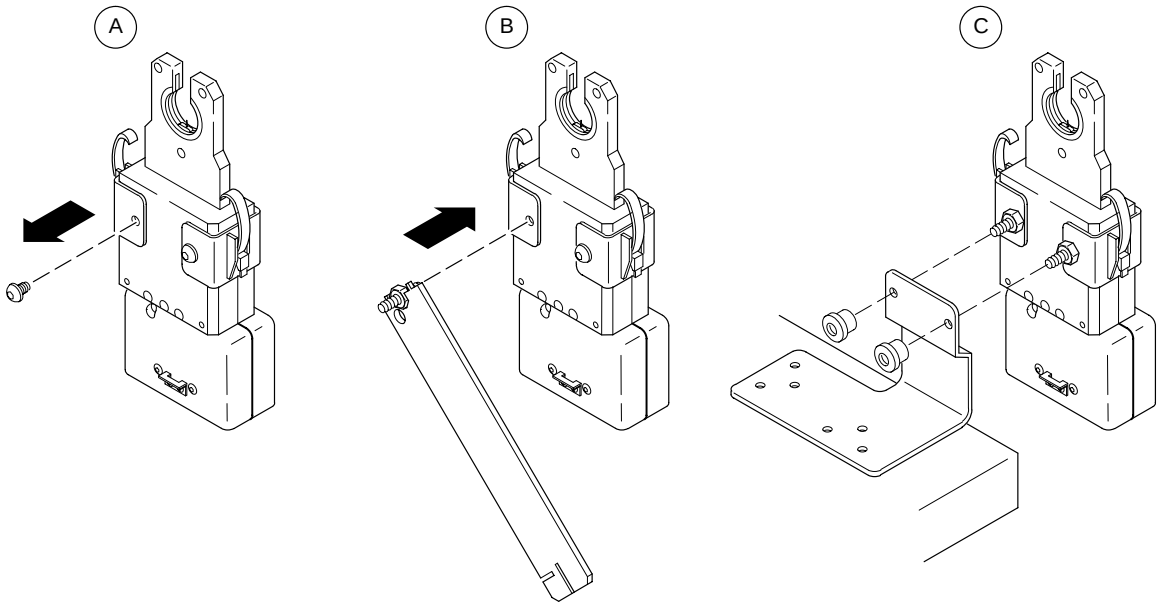


Figure 4-18 Using the Series 8 Bench Mount Bracket

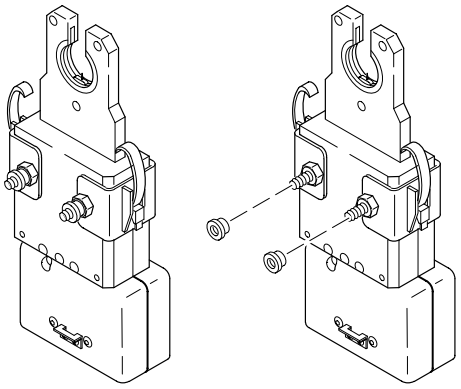


Figure 4-19 Storing the Thumb Nuts on the Adapter Screws

6. Secure the weld head using the two knurled thumb nuts supplied with the bench mounting bracket.

   Keep the thumb nuts on the adapter screws when not using the bench mount bracket. See Figure 4-19.

Section 5
Weld Parameter Adjustment

Introduction

This section describes the procedures necessary for adjusting weld parameters to create welds that meet required specifications. This section includes:

- developing a weld procedure guideline
- evaluating the weld
- adjusting controls for weld quality.

Developing a Weld Procedure Guideline

In order to create a weld that meets the required specifications, you may need to adjust the welding parameters. You start with the weld procedure guideline worksheet found on page 5-10. The steps in the worksheet show you how to develop the speed, current, and timing for the Swagelok Welding System (SWS).

The example in the following procedure is based on 1/2 in. OD, 0.049 in. wall thickness 316L stainless steel tubing using the Series 5 Weld Head. The procedure applies for all weld heads.

Note: *This procedure assumes you are fusion butt welding austenitic stainless steel tubing.*

Note: *This procedure is only a guideline. The final weld quality depends on the operator's welding experience and on the proper use of welding techniques.*

To develop a weld procedure guideline, follow these steps:

Locate the Example Weld Procedure Guideline Worksheet found on page 5-9. Each of the following steps on pages 5-2 through 5-8 corresponds to the steps on the example worksheet. After completing each step, verify the recorded value on the example worksheet. A blank worksheet is included on page 5-10 for you to use when creating your own weld procedure guidelines.

The values in parenthesis ( ) in the procedure correspond to the steps in the Example Weld Procedure Guideline Worksheet found on page 5-9.

Determining the Work Specifications

1. Determine the outside diameter (1/2 in.) of the tubing or fitting at the weld joint.

2. Determine the wall thickness (0.049 in.) of the tubing or fitting at the weld joint.

3. Select the weld head model (CWS-5H-B).

Note: *The electrode length and diameter depend on the weld head model and the outside diameter of the components.*

4. Refer to the Electrode Selection Tables in Appendix C, *Electrode Selection Tables and Geometry.* Select the proper electrode (CWS-C.040-.605-P).

Note: *Most applications use an arc gap of 0.035 in. The proper arc gap gage setting depends on the weld head model and the outside diameter of the components.*

5. Refer to the Weld Head Arc Gap Gage tables in Appendix E, *Arc Gap Gage Setting Tables*. Set the arc gap (0.907 in.) in the arc gap gage with either a caliper or micrometer.

Setting the Front Panel Switches

1. Select a travel speed (5 in./min).

Note: *A travel speed of 3 in./min to 15 in./min is a general range for GTAW welding.*

Average Travel Speeds [(OD Speed + Wall Speed) ÷ 2] = Corrected Travel Speed

Table 5-1 Travel Speed Setting Chart − Fractional

Wall Thickness (in.)	Travel Speed (in. per min)	OD Size (in.)	Travel Speed (in. per min)
.015 to .030	8	1/16 to 3/16	8
.031 to .040	7	1/4 to 1/2	7
.041 to .055	6	5/8 to 3/4	5
.056 to .065	5	7/8 to 1	4
.066 to .079	4	1 to 1 1/2	4
.080 to .090	4	1 5/8 to 2	3
.091 to .109	3		

Table 5-2 Travel Speed Setting Chart − Metric

Wall Thickness (mm)	Travel Speed (mm per sec)	OD Size (mm)	Travel Speed (mm per sec)
0,38 to 0,76	3,39	3 to 6	3,39
0,78 to 1,00	2,96	6 to 12	2,96
1,04 to 1,40	2,54	16 to 19	2,12
1,42 to 1,65	2,12	22 to 25	1,69
1,66 to 2,00	1,69	25 to 38	1,69
2,03 to 2,28	1,69	40 to 52	1,27
2,30 to 2,76	1,27		

2. Refer to the Rotor Speed switch setting graphs on pages 5-11 through 5-12. Calculate the Rotor Speed:
   a. Locate the appropriate graph based upon the weld head model (CWS-5H-B).
   b. Locate the travel speed (5 in./min) at the bottom of the graph.
   c. From that point, draw a vertical line up until the line intersects the line representing the work piece tubing outside diameter (1/2 in.).
   d. From that point, draw a horizontal line to the right to find the switch setting (26).
   e. Set **ROTOR SPEED** according to the result (26) in step 2.d.

Note: *The* **ROTOR SPEED** *setting is a percentage of the maximum weld head revolutions per minute. For example, 25 is 25 % of the maximum speed of the CWS-5H-B weld head.*

3. Calculate the Impulse:

   a. Determine the wall thickness (0.049 in.).

   b. Locate the wall thickness (0.049 in.) and the corresponding "A" factor in Table 5-3.

Table 5-3 Wall Thickness and "A" Factor

Wall Thickness Range		
in.	**mm**	**"A" Factor**
0.015 to 0.045	0,381 to 1,143	1.1
0.046 to 0.083	1,168 to 2,108	1.2
0.084 to 0.109	2,133 to 2,769	1.3

   c. Calculate the Impulse using the following formula:

   "A" × wall thickness × 1000 = switch setting

   For example, for a wall thickness of 0.049 in.:

   1.2 × 0.049 in. × 1000 = 58.8 A

   d. Set **IMPULSE** (58.8) according to the result of the formula in step 3.c.

Note: *Because the* **IMPULSE** *switch accepts values to only one decimal place, you may need to round off the number. Since 58.8 is already to one decimal place, it does not need rounding.*

Note: *If the* **IMPULSE** *calculation result is equal to or greater than 99.9 A, set the* **IMPULSE** *to 99.9.*

4. Calculate the Maintenance:

   a. Locate the wall thickness (0.049 in.) and the corresponding "B" factor in Table 5-4.

Table 5-4 Wall Thickness and "B" Factor

Wall Thickness Range		
in.	**mm**	**"B" Factor**
0.015 to 0.045	0,381 to 1,143	0.25
0.046 to 0.083	1,168 to 2,108	0.30
0.084 to 0.109	2,133 to 2,769	0.40

b. Calculate the Maintenance using the following formula:

Impulse current × "B" = switch setting

For example, for a wall thickness of 0.049 in.:

58.8 A × 0.30 = 17.64 = 17.6 A

c. Set **MAINTENANCE** (17.6) according to the result of the formula in step 4.b.

5. Set **IMPULSE RATE** to 10.

6. Calculate the Impulse Width:

a. Locate the wall thickness (0.049 in.) and the corresponding "C" factor in Table 5-5.

Table 5-5 Wall Thickness and "C" Factor

Wall Thickness Range		"C" Factor
in.	mm	
0.015 to 0.045	0,381 to 1,143	25
0.046 to 0.083	1,168 to 2,108	35
0.084 to 0.109	2,133 to 2,769	50

b. Set **IMPULSE WIDTH** (35) according to Table 5-5.

Note: *If the* **IMPULSE** *is greater than 99.9 A, set the* **IMPULSE** *to 99.9. However, use the actual value to calculate the Maintenance.*

For example, if the **IMPULSE** *is 102 A, set the* **IMPULSE** *to 99.9, but use 102 to calculate the Maintenance.*

Note: *Because the* **MAINTENANCE** *switch accepts values to only one decimal place, you may need to round off the number. For example, 17.64 is rounded off to 17.6.*

Note: *As a general guideline, set the* **IMPULSE RATE** *between 5 cycles per second to 25 cycles per second. A setting of ten is a general starting point. However, as the tube outside diameter decreases, the Impulse Rate value increases.*

Refer to "Identifying Proper Welds" on page 5-17 to see the effect of the Impulse Rate on the weld.

7. Calculate the Arc Start:

   a. Calculate the Arc Start using the following formula:

Note: *The minimum* **START** *setting is 2.*

(Impulse% × Impulse Width) + [maint. × (1 − % Impulse Width)] = Arc Start

Note: Enter the Impulse Width in the formula as a percentage.

Using the values in this example:

(58.8 x 0.35) + [17.6 x (1 − 0.35)] = 32.02 = 32 A

   b. Set **ARC START** (32) according to the results of the formula in step 7.a.

8. Calculate the Duration:

   a. Locate the wall thickness (0.049 in.) and the corresponding "D" factor in Table 5-6.

Table 5-6 Wall Thickness and "D" Factor

Wall Thickness Range		
in.	**mm**	**"D" Factor**
0.015 to 0.045	0,381 to 1,143	0.3
0.046 to 0.083	1,168 to 2,108	0.5
0.084 to 0.109	2,133 to 2,769	1.0

   b. Set **DURATION** (0.5) according to Table 5-6.

9. Set **PREPURGE** to 10.

   Use a continuous purge when using the micro weld head by pressing the **PURGE** pushbutton.

Note: *The suggested minimum Prepurge time is 10 seconds for all weld heads. Higher Prepurge times may be necessary for certain applications.*

When using a weld head extension cable, increase the Prepurge time one second for each foot of extension length.

10. Refer to the Rotor Speed switch setting graphs on pages 5-11 through 5-12. Calculate the Weld Time:

    a. Locate the appropriate graph based upon the weld head model (CWS-5H-B).

    b. Locate the Rotor Speed (26; from step 2.e. on page 5-3) on the graph.

    c. From that point, extend a horizontal line to the right until it intersects the seconds/revolution curve.

    d. Drop a vertical line down from that point on the curve to find the seconds per revolution (19).

    e. The Weld Time setting depends on the tubing outside diameter. If the outside diameter is:

    - less than or equal to 1/2 in.*, multiply the seconds per revolution by two and set **WELD TIME** according to that result.

      For example, since the tubing in this example has an outside diameter of 1/2 in., the Weld Time is:

      $19 \times 2 = 38$

    - greater than 1/2 in., set **WELD TIME** according to the result in step 10.d.

    For example, the Weld Time is 19 for a single-pass weld and 38 for a two-pass weld based upon the following criteria:

    - **ROTOR SPEED**: 25
    - Seconds per revolution: 19
    - Seconds per revolution for a single-pass weld: 19
    - Seconds per revolution for a two-pass weld: $19 \times 2 = 38$

Note: *Experience suggests that tubing with an outside diameter of less than or equal to 1/2 in. typically requires two revolutions (two passes). Tubing with a larger outside diameter requires one revolution (one pass).*

***Caution!**

When welding 1/2 in. or 12 mm outside diameters with the 8MRH Weld Head, use a single pass (one revolution) weld procedure only.

11. Calculate the Downslope:

    a. Calculate the Downslope using the following formula:

       Weld Time × 0.5 = switch setting

       For example, using the Weld Time of 38 in step 10.e.:

       38 × 0.5 = 19

    b. Set **DOWNSLOPE** (19) according to the result of the formula in step 11.a.

12. Set **POSTPURGE** to 20.

Note: *The suggested minimum Postpurge time is 20 seconds. This time allows for sufficient cooling of the electrode and weld zone. Additional Postpurge time may be necessary for a weld made with a high average current setting.*

Example Weld Procedure Guideline Worksheet

Determine the Work Specifications

Step	Parameter	Setting
1	Weld Diameter	1/2 in.
2	Wall Thickness	0.049 in.
3	Weld Head Model No.	5H-B
4	Electrode Part No.	CWS-C.040-.605-P
5	Arc Gap Gage Setting	0.907 in.
6	Weld Head Shielding Gas Flow	12
7	ID Purge Gas Flow	4

Calculating Weld Parameters

Step	Parameter	Setting
1	**TRAVEL SPEED** (in./min)	5 in./min
2	**ROTOR SPEED**	26 %
3	**IMPULSE** "A" × wall thickness × 1000 = **IMPULSE** 1.2 × 0.049 in. × 1000 = 58.8	58.8 A
4	**MAINTENANCE** "B" × Impulse = **MAINTENANCE** 0.30 × 58.8 = 17.64 = 17.6	17.6 A
5	**IMPULSE RATE**	10 cycles/s
6	**IMPULSE WIDTH**	35 %
7	**ARC START** (imp. × %imp. width) + [maint. × (1−%imp. width)] = **ARC START** (58.8 × 0.35) + [17.6 × (1−0.35)] = 32.02 = 32	32 A
8	**DURATION**	0.5 s
9	**PREPURGE**	10 s
10	**WELD TIME** • If tube outside dia ≤ 1/2 in.: s/rev. × 2 = **WELD TIME** 19 × 2= 38 • If tube outside dia > 1/2 in.: s/rev. = **WELD TIME**	38 s
11	**DOWNSLOPE** Weld Time × 0.5 = **DOWNSLOPE** 38 × 0.5 = 19	19 s
12	**POSTPURGE**	20 s

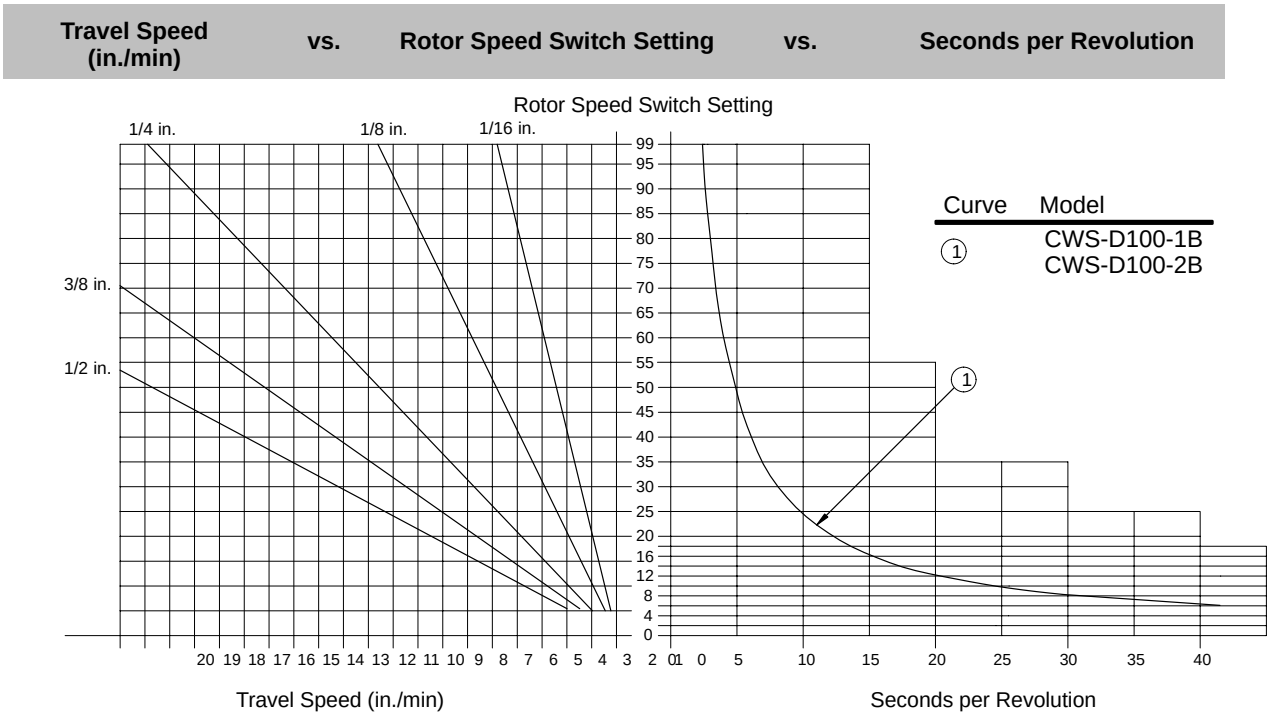
Weld Procedure Guideline Worksheet

Determine the Work Specifications

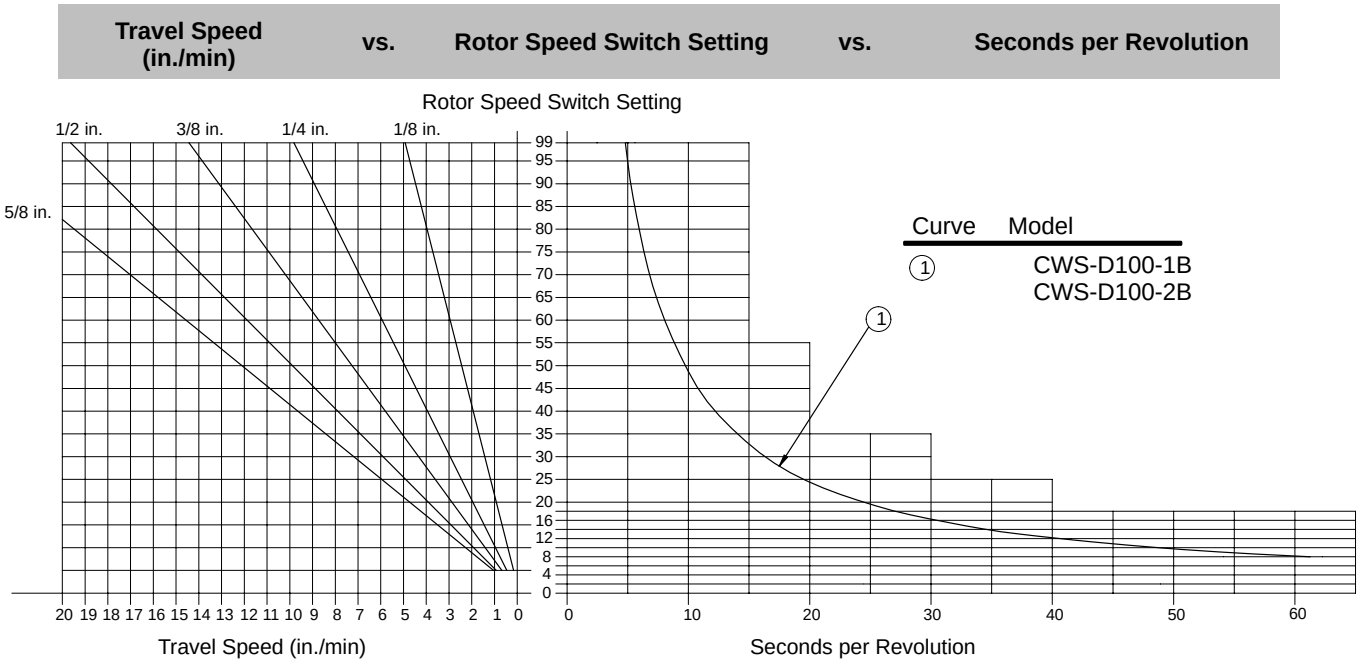
Step	Parameter	Setting
1	Weld Diameter	
2	Wall Thickness	
3	Weld Head Model No.	
4	Electrode Part No.	
5	Arc Gap Gage Setting	
6	Weld Head Shielding Gas Flow	
7	ID Purge Gas Flow	

Calculating Weld Parameters

Step	Parameter	Setting
1	**TRAVEL SPEED** (in./min)	
2	**ROTOR SPEED**	
3	**IMPULSE** "A" × Wall Thickness × 1000 = **IMPULSE** × × 1000 = _____	
4	**MAINTENANCE** "B" × Impulse = **MAINTENANCE** × = _____	
5	**IMPULSE RATE**	
6	**IMPULSE WIDTH**	
7	**ARC START** (Imp. × %Imp. Width) + [Maint. × (1−%Imp. Width)] = **ARC START** (×) + [× (1 −)] =	
8	**DURATION**	
9	**PREPURGE**	
10	**WELD TIME** • If tube outside dia ≤ 1/2 in.: s/rev. × 2 = **WELD TIME** _____ × 2= • If tube outside dia > 1/2 in.: s/rev. = **WELD TIME** _____ =	
11	**DOWNSLOPE** Weld Time × 0.5 = **DOWNSLOPE** _____ × 0.5 =	
12	**POSTPURGE**	

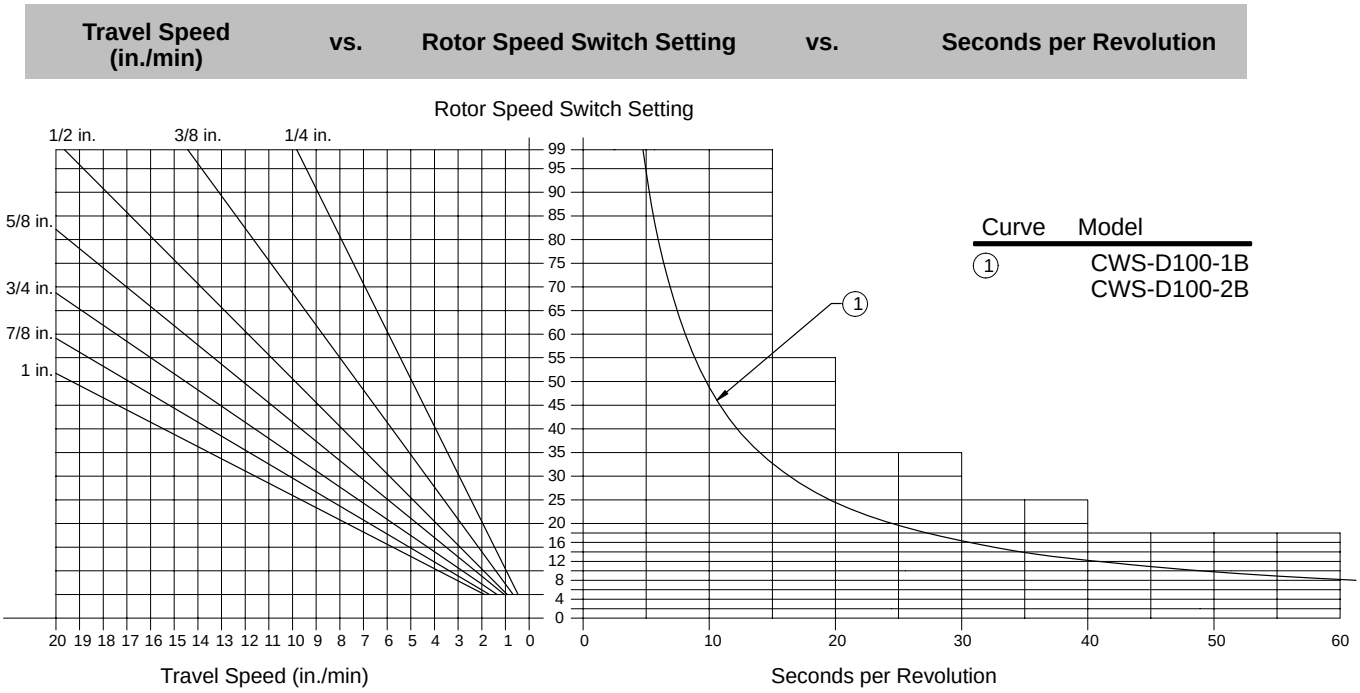


MICRO WELD HEAD − TUBE WELDING

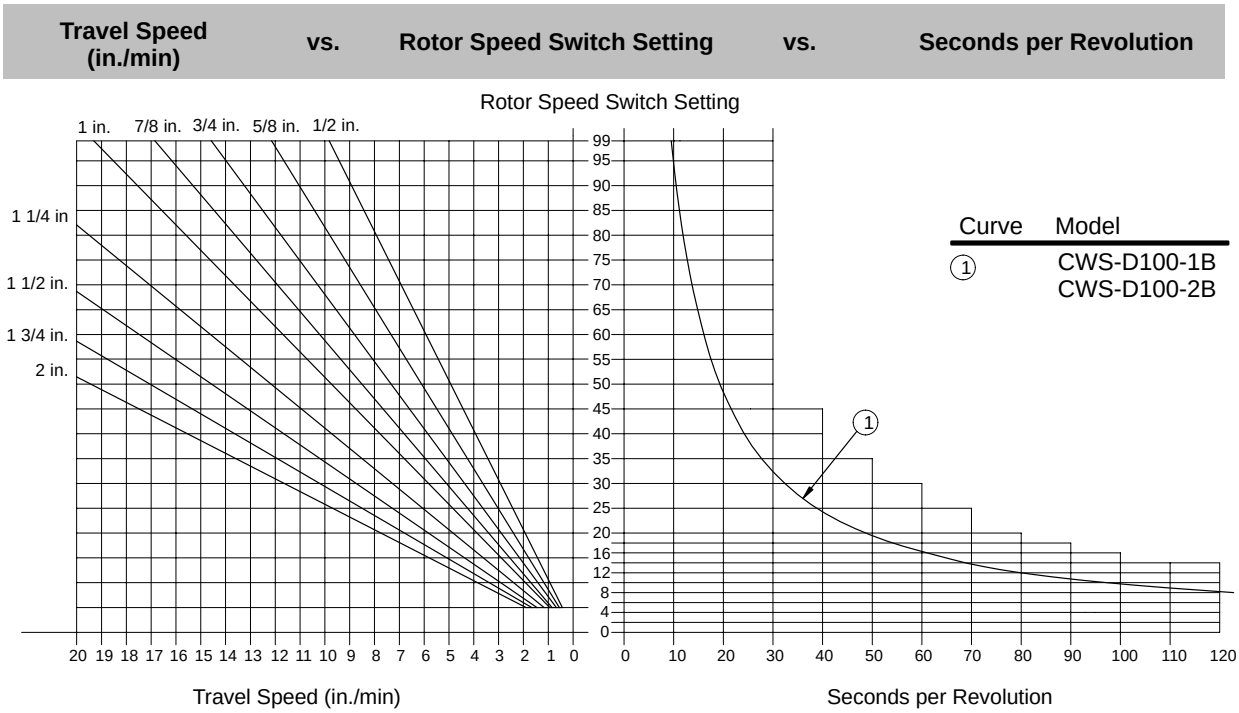


SERIES 5 WELD HEAD − TUBE WELDING

Figure 5-1 Rotor Switch Speed Setting Graphs (Micro Weld Head, Series 5 Weld Head)− Fractional

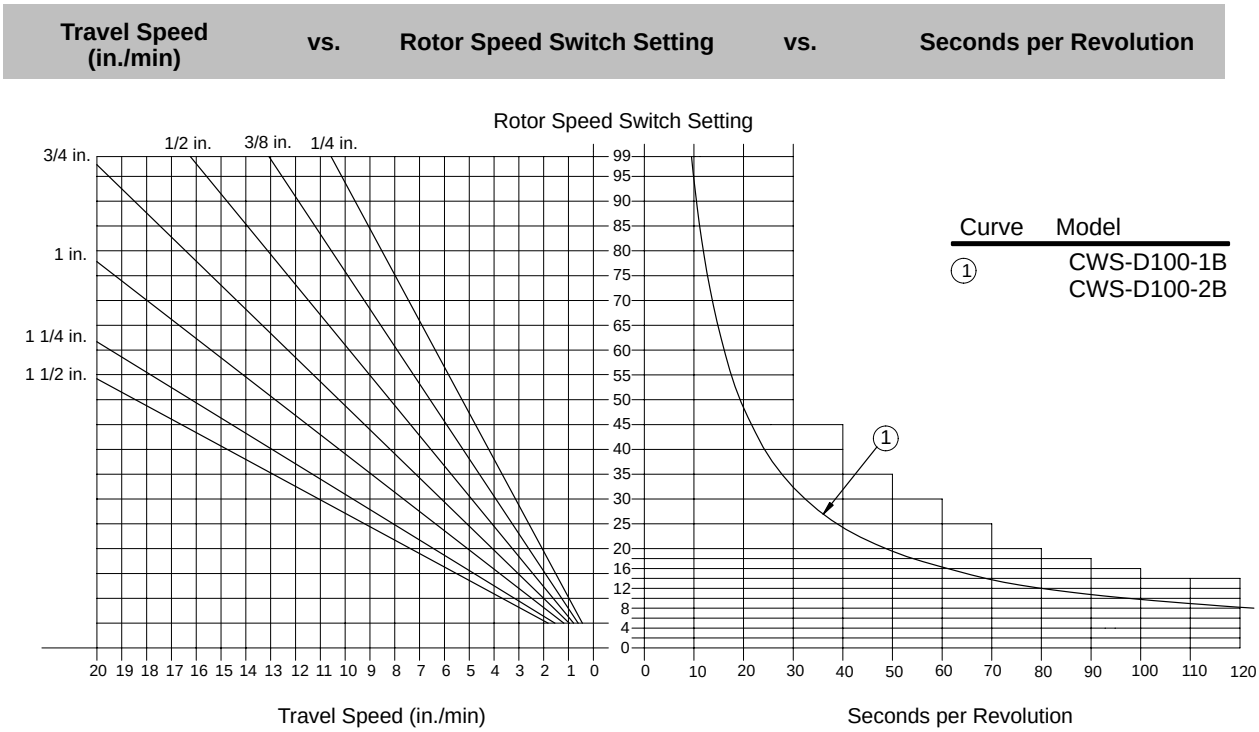


SERIES 10 WELD HEAD − TUBE WELDING



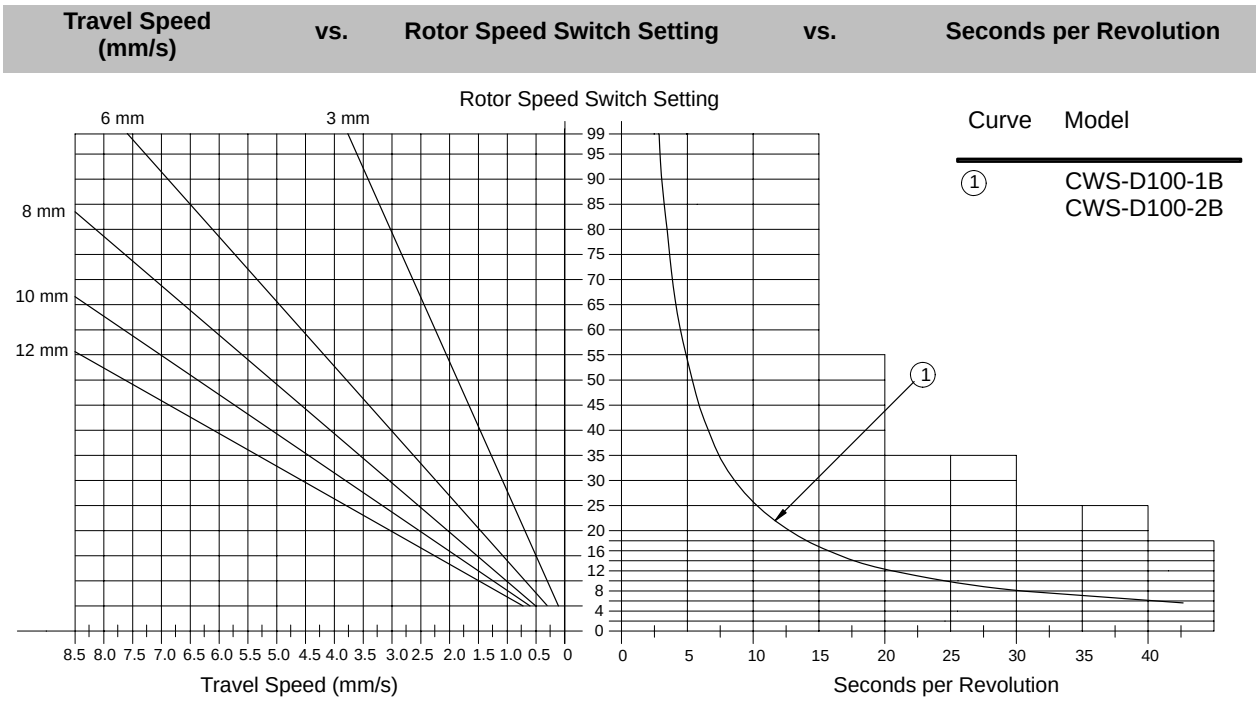
SERIES 20 WELD HEAD − TUBE WELDING

Figure 5-2 Rotor Switch Speed Setting Graphs
(Series 10 Weld Head, Series 20 Weld Head)− Fractional

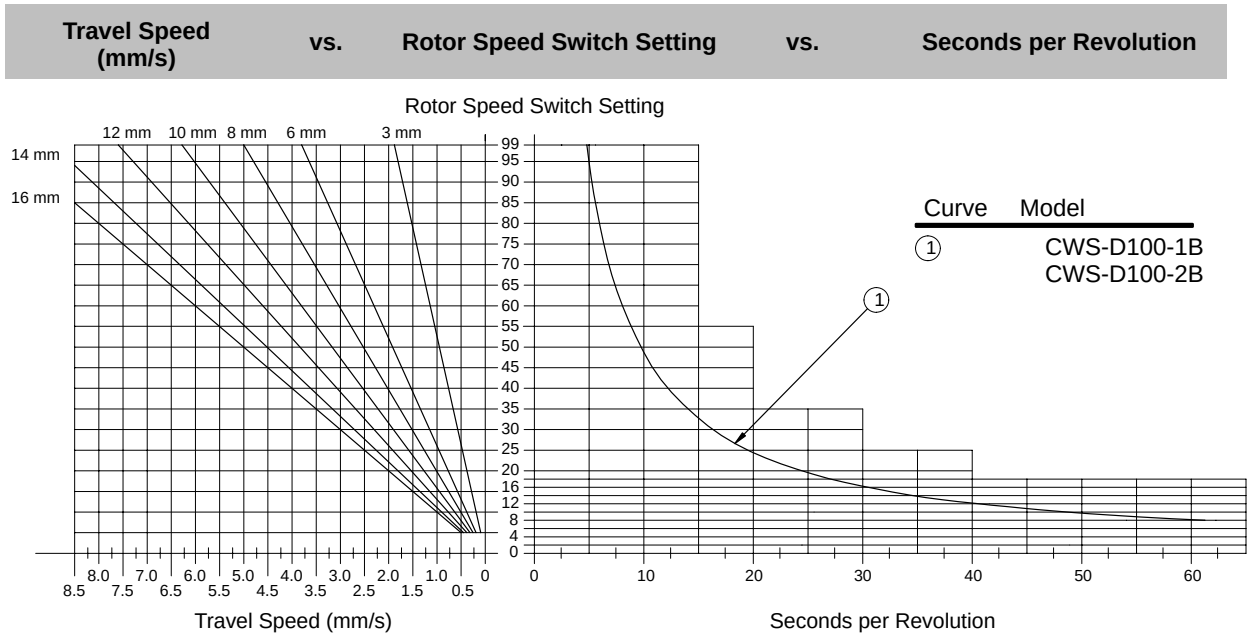


SERIES 20 WELD HEAD − PIPE WELDING

Figure 5-3 Rotor Switch Speed Setting Graphs (Series 20 Weld Head)− Fractional



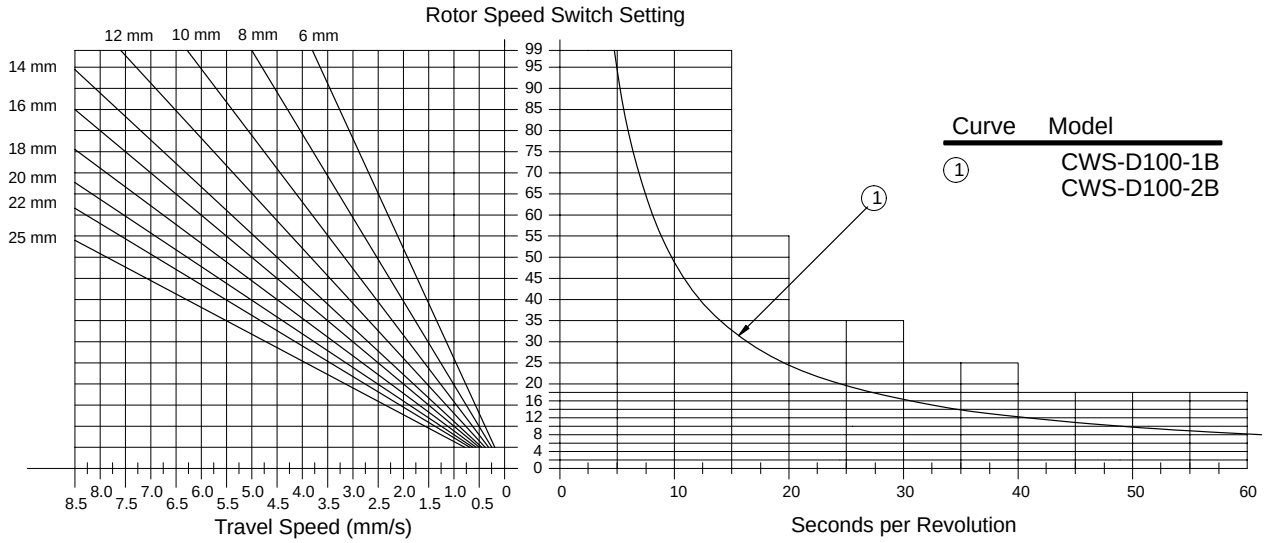
MICRO WELD HEAD − TUBE WELDING



SERIES 5 WELD HEAD − TUBE WELDING

Figure 5-4 Rotor Switch Speed Setting Graphs (Micro Weld Head, Series 5 Weld Head)− Metric

Travel Speed (mm/s)	vs.	Rotor Speed Switch Setting	vs.	Seconds per Revolution



SERIES 10 WELD HEAD − TUBE WELDING

Travel Speed (mm/s)	vs.	Rotor Speed Switch Setting	vs.	Seconds per Revolution

SERIES 20 WELD HEAD − TUBE WELDING

Figure 5-5 Rotor Switch Speed Setting Graphs
(Series 10 Weld Head, Series 20 Weld Head) − Metric

Evaluating the Weld

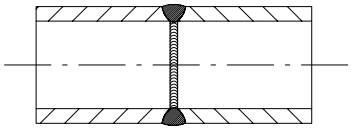


Figure 5-6 Good Weld

A completed weld must meet structural and metallurgical requirements. The weld must be uniform, be free from cracks, porosity, and undercuts. It must not have excessive oxidation. And, if it is a butt weld, it must have full penetration from the outside diameter to the inside diameter. See Figure 5-6.

Identifying Typical Weld Discontinuities

Figure 5-7 shows typical weld discontinuities.

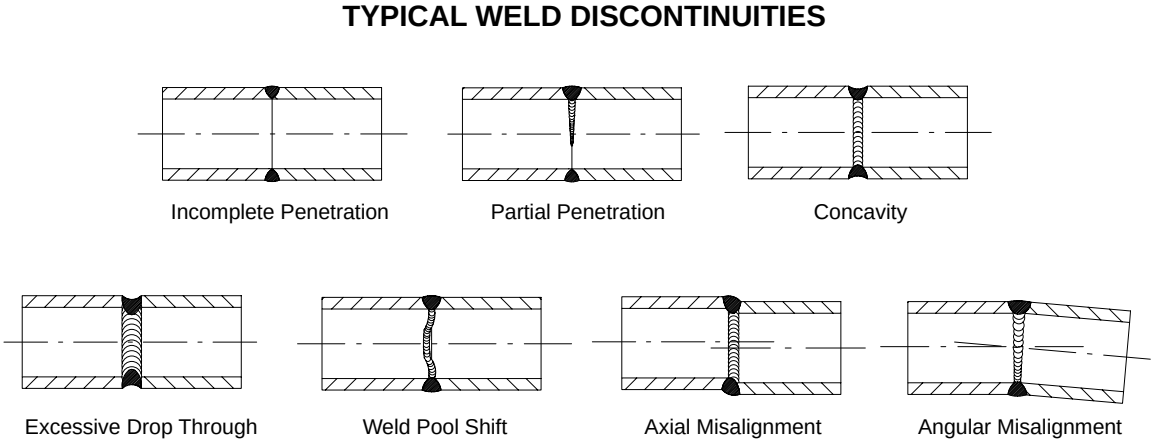


Figure 5-7 Typical Weld Discontinuities

Identifying Proper Welds

The cross-sectional welds in Figure 5-8 through Figure 5-19 on pages 5-17 through 5-22 show how changing various parameters affects the shape of the weld.

To check the weld, follow these steps:

1. Inspect the weld on the outside of the tube. Check for
   - uniformity
   - cracks
   - undercuts
   - excessive oxide.
2. Inspect the weld on the inside of the tube. Check for
   - uniformity, cracks, undercuts, and excessive oxidation
   - full penetration
   - excessive weld bead width variations
   - excessive weld-spot overlap.

Reference Weld

Figure 5-8 shows a cross-section of a proper weld. The weld shows full penetration from the outside diameter to the inside diameter, a crown on the outside diameter, and minimal weld bead dropthrough on the inside diameter.

Note: *The welds are made with a 316L stainless steel tube with the following dimensions: 1/2 in. OD, 0.049 in. wall thickness.*

Table 5-7 lists the parameters used to create the weld. Compare welds with Figure 5-8.

Table 5-7 Reference Weld Parameters

Parameter	Setting
Impulse (Amperes)	58.8
Maintenance (Amperes)	17.6
Impulse Rate	10
Impulse Width	35
Speed (s/rev)	26 (19)
Arc Gap	0.035 in.
Avg. Current Display (Amperes)	32

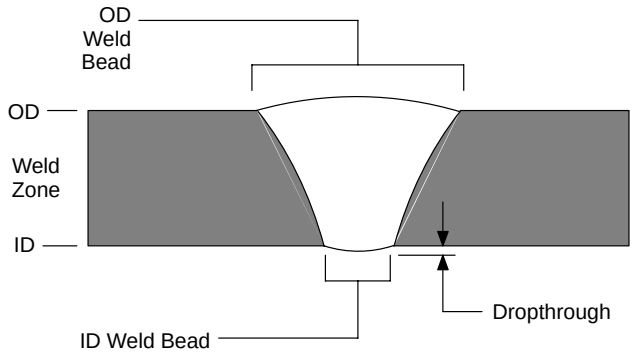


Figure 5-8 Reference Weld Illustration

The following examples show how changes in various parameters can affect the weld shape.

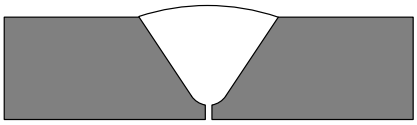


Figure 5-9 Weld Example No. 1

Weld Example No. 1

Table 5-8 lists the parameter change used to create the weld shown in Figure 5-9.

Table 5-8 Weld Example No. 1

Parameter	Reference Setting	This Setting
Impulse (Amperes)	58.8	49.8
Average Current Display (Amperes)	32	28.87

Lowering the Impulse current lowers the average current. This decreases the heat input per unit of electrode travel resulting in no inside diameter penetration.

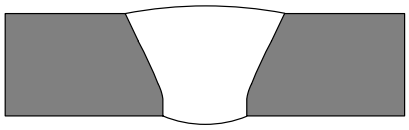


Figure 5-10 Weld Example No. 2

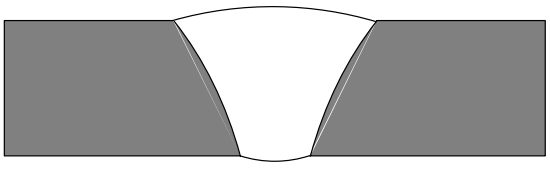
Weld Example No. 2

Table 5-9 lists the parameter change used to create the weld shown in Figure 5-10.

Table 5-9 Weld Example No. 2

Parameter	Reference Setting	This Setting
Impulse (Amperes)	58.8	67.9
Average Current Display (Amperes)	32	35.2

Raising the Impulse current raises the average current. This increases the heat input per unit of electrode travel resulting in increased inside diameter dropthrough and weld bead width.



Reference Weld Illustration

Weld Example No. 3

Table 5-10 lists the parameter change used to create the weld shown in Figure 5-11.

Table 5-10 Weld Example No. 3

Parameter	Reference Setting	This Setting
Maintenance (Amperes)	17.8	14.8
Average Current Display (Amperes)	32	30.2

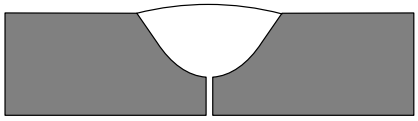


Figure 5-11 Weld Example No. 3

Lowering the Maintenance current lowers the average current. This decreases the heat input per unit of electrode travel resulting in no inside diameter penetration.

Weld Example No. 4

Table 5-11 lists the parameter change used to create the weld shown in Figure 5-12.

Table 5-11 Weld Example No. 4

Parameter	Reference Setting	This Setting
Maintenance (Amperes)	17.8	20.8
Average Current Display (Amperes)	32	34.1

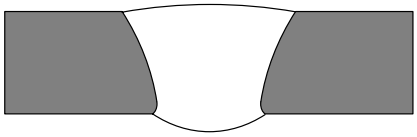
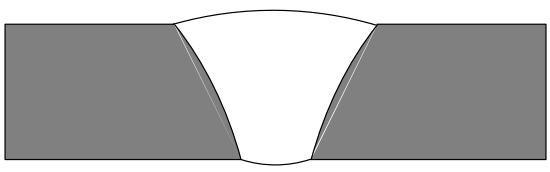


Figure 5-12 Weld Example No. 4

Raising the Maintenance current raises the average current. This increases the heat input per unit of electrode travel resulting in increased inside diameter dropthrough and weld bead width.



Reference Weld Illustration

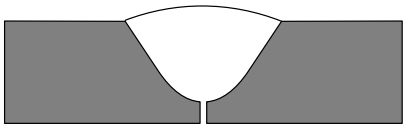


Figure 5-13 Weld Example No. 5

Weld Example No. 5

Table 5-12 lists the parameter change used to create the weld shown in Figure 5-13.

Table 5-12 Weld Example No. 5

Parameter	Reference Setting	This Setting
Impulse Width	35	30
Average Current Display (Amperes)	32	30

Shortening the Impulse Width lowers the average current. This decreases the heat input per unit of electrode travel resulting in no inside diameter penetration.

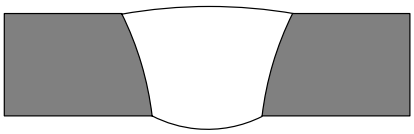


Figure 5-14 Weld Example No. 6

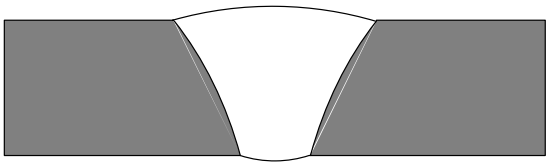
Weld Example No. 6

Table 5-13 lists the parameter change used to create the weld shown in Figure 5-14.

Table 5-13 Weld Example No. 6

Parameter	Reference Setting	This Setting
Impulse Width	35	40
Average Current Display (Amperes)	32	34

Lengthening the Impulse Width raises the average current. This increases the heat input per unit of electrode travel resulting in increased inside diameter dropthrough and weld bead width.



Reference Weld Illustration

Weld Example No. 7

Table 5-14 lists the parameter change used to create the weld shown in Figure 5-15.

Table 5-14 Weld Example No. 7

Parameter	Reference Setting	This Setting
Speed (s/rev)	26 (19)	33 (15)

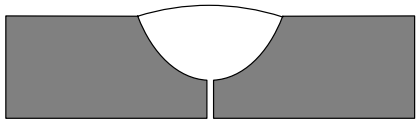


Figure 5-15 Weld Example No. 7

Raising the Rotor Speed decreases the heat input per unit of electrode travel resulting in no inside diameter penetration.

Weld Example No. 8

Table 5-15 lists the parameter change used to create the weld shown in Figure 5-16.

Table 5-15 Weld Example No. 8

Parameter	Reference Setting	This Setting
Speed (s/rev)	26 (19)	19 (26)

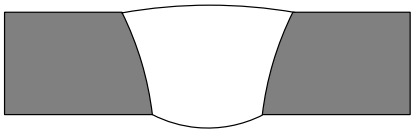
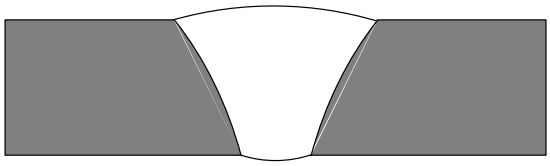


Figure 5-16 Weld Example No. 8

Lowering the Rotor Speed increases the heat input per unit of electrode travel resulting in increased inside diameter dropthrough and weld bead width.



Reference Weld Illustration

Figure 5-17 Impulse Rate Reference Weld

Impulse Rate Reference Weld

Table 5-16 lists the parameter used to create the reference weld shown in Figure 5-17.

Table 5-16 Impulse Rate Reference Weld

Parameter	Reference Setting	This Setting
Impulse Rate	10	10

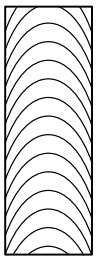


Figure 5-18 Impulse Rate Weld Example No. 1

Impulse Rate Weld Example No. 1

Table 5-17 lists the parameter change used to create the weld shown in Figure 5-18.

Table 5-17 Weld Example No. 1

Parameter	Reference Setting	This Setting
Impulse Rate	10	05

Lowering the frequency reduces weld-spot overlap.

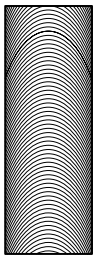


Figure 5-19 Impulse Rate Weld Example No. 2

Impulse Rate Weld Example No. 2

Table 5-18 lists the parameter change used to create the weld shown in Figure 5-19.

Table 5-18 Weld Example No. 2

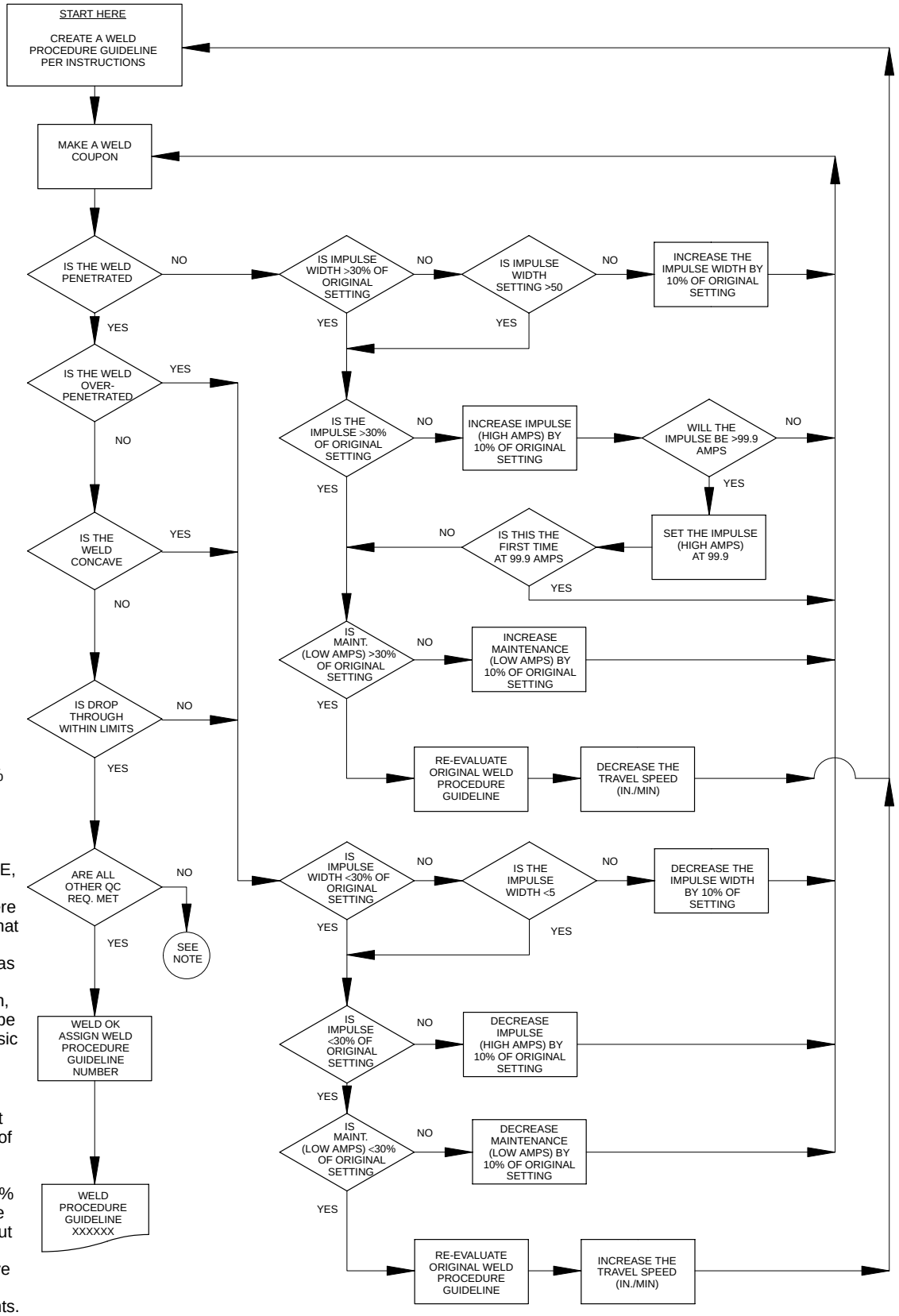
Parameter	Reference Setting	This Setting
Impulse Rate	10	25

Raising the frequency increases weld-spot overlap.

Adjusting Controls for Weld Quality

At times, the welding parameters (as described on page 5-9) must be adjusted to create an acceptable weld.

Use the flow chart in Figure 5-20 to assist in adjusting the weld parameters.



This chart is an aid for reference only to help meet general requirements for 100 % autogenous fusion butt welds in stainless steel tubing and fittings. It uses the basic parameters of IMPULSE, MAINTENANCE and IMPULSE WIDTH. There are other parameters that can be used to control weld quality, such as gas purge, arc gap, weld speed, joint preparation, etc. These issues can be addressed after the basic criteria have been met.

NOTE: The welds must meet the basic criteria of being structurally and metallurgically sound. The weld must be 100 % penetrated to the inside diameter surface without reducing the flow path. The weld may also have to meet additional cleanliness requirements.

Figure 5-20 Weld Procedure Guideline Flowchart

Section 6
Maintenance

Introduction

To ensure your Swagelok Welding System (SWS) equipment is always in proper working order, you must perform periodic maintenance on the system components.

This section describes the procedures necessary for maintaining the fixture blocks, weld heads, and power supply.

For detailed part drawings and information, refer to Appendix F, *Parts Drawings*.

Note: *If you experience problems while performing the procedures in this section, refer to Section 7,* Troubleshooting*, or contact your Swagelok representative.*

Replace any defective parts. Service replacement kits are available through your Swagelok representative.

Series 5/10/20 Fixture Blocks

Perform fixture block maintenance daily and after every 40 hours of welding time. If desired, maintenance may be performed before the 40-hour interval.

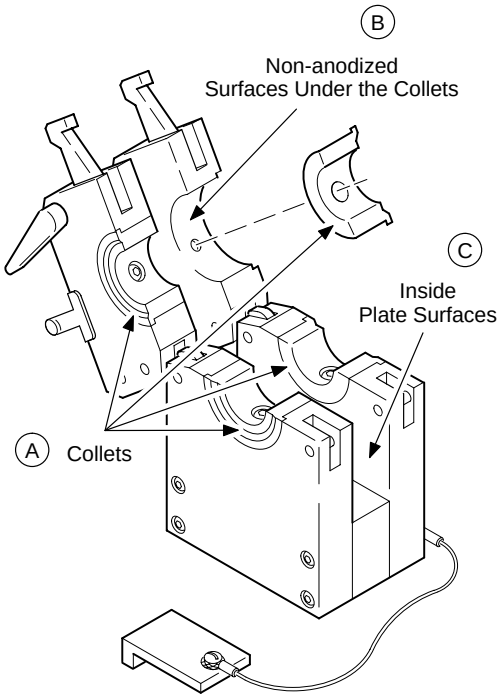


Figure 6-1 Cleaning the Collets and Collet Mounting Surfaces

Daily Maintenance

At the start of each work day:

1. Inspect the fixture block for cleanliness.
2. Remove dirt, carbon, and vapor deposits from the fixture block with a clean, soft cloth. A solvent such as alcohol or acetone can be used. Remove heavier deposits with a fine-grit abrasive pad.

At the end of each work day, clean and then store the fixture block in a dry place.

Forty-Hour Maintenance

Every 40 hours:

1. Inspect and clean the collets. See Figure 6-1(A).
   a. Check for scratches and dents.
   b. Remove dirt and oxides from all surfaces of the collet with the a soft stainless steel wire brush.
2. Remove any oxides from the non-anodized mating surfaces of the side plates with a fine-grit abrasive pad. See Figure 6-1(B).
3. Remove any dirt and oxides from the inside surfaces of the side plates with a clean, soft cloth. See Figure 6-1(C). Remove heavier deposits with a fine-grit abrasive pad.
4. Check the lever cam and latch for smooth operation. See Figure 6-2.

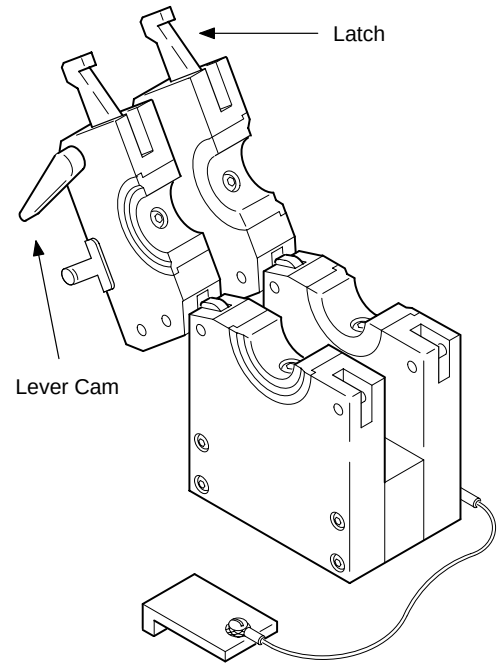


Figure 6-2 Lever Cam and Latch

Micro Weld Head Fixture Blocks

The micro weld head fixtures require regular cleaning and maintenance.

Daily Maintenance

1. Clean the surfaces of the fixture that contact the work pieces. Use the wire brush included in the micro weld head accessory package. See Figure 6-3.

2. If applicable, check the fixture insulating tape for damage. Replace the tape if it is loose or torn, exposing the metal under it.. See Figure 6-4.

   To replace the tape:

   a. Remove the damaged tape from both sides of the fixture.

      Disassembly of the CWS-8MF-08 and CWS-8MF-12MM may be necessary to assist in replacing the tape. Disassemble by removing the screws which hold the arc covers on each side of the fixture. Refer to page F-48 in Appendix F, *Part Drawings*.

   b. Clean the surfaces with alcohol or acetone.

   c. Apply one end of the pre-cut tape strip to the inside edge of the underside surface. The tape should wrap in the direction shown in Figure 6-4.

   d. Wrap the tape tightly (approximately 1 1/2 turns). The tape should end at the outside edge of the top surface.

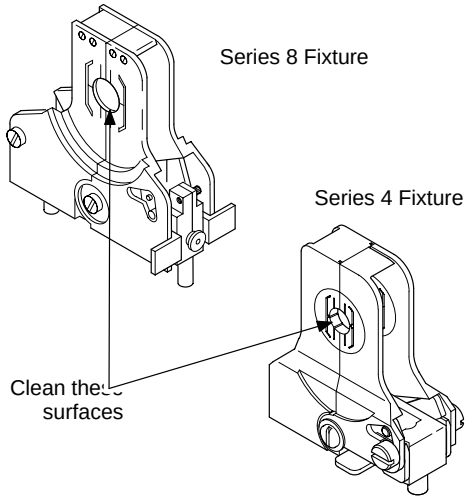


Figure 6-3 Cleaning the Micro Weld Head Fixtures

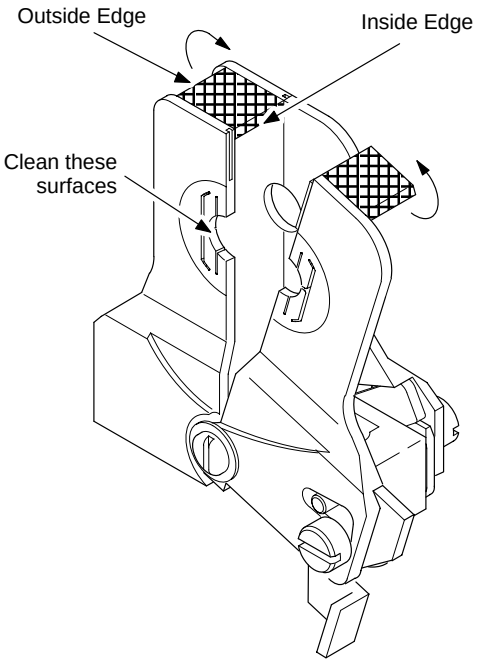


Figure 6-4 Checking/replacing the Insulator Tape

Series 5/10/20 Weld Head

WARNING!

Disconnect the weld head from the power supply before performing the adjustment or maintenance.

Perform weld head maintenance daily and every 40 hours of welding time. If desired, maintenance may be performed before the 40-hour interval.

Daily Maintenance

At the start of each work day:

1. Inspect the weld head for cleanliness. Pay close attention to the rotor area. See Figure 6-5.

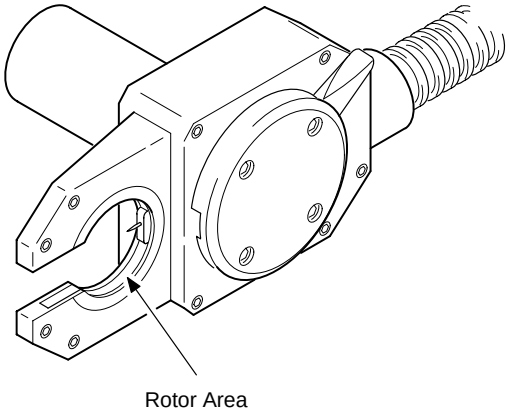


Figure 6-5 Inspect Exposed Surfaces of the Weld Head

2. Press **STOP/RESET**. Check the rotor for smooth rotation. If the rotation is erratic or noisy, disassemble the weld head and clean the rotor, gears, and brush. See page 6-5, “Series 5/10/20 Weld Head Disassembly and Cleaning.”

At the end of each work day:

1. Remove dirt, carbon, and vapor deposits from the weld head with a clean, soft cloth and a solvent such as alcohol or acetone.

2. Store the weld head in a clean, dry place.

Forty-Hour Maintenance

Every 40 hours, measure the rotor speed to ensure its accuracy. For example:

1. Set **ROTOR SPEED** to one of the following values:

   - 19 for a micro and Series 5/10 Weld Head
   - 38 for a Series 20 Weld Head

   This sets a rotor speed of 13 seconds per revolution for the micro weld head and 26 seconds per revolution for the Series 5/10/20 Weld Head.

Caution!

Do not use lubricants inside the weld head.

2. While watching the rotor status LED, press and hold **ROTOR JOG** and note the rotor travel time using a stopwatch. The rotor should move for 13 seconds. Repeat the test two or three times to get an accurate average travel time.

   The travel distance for Series 5/10/20 Weld Heads is one half revolution. The micro weld head moves one revolution.

3. Compare the actual rotor travel time to the 13 second reference.

   If the measured speed differs more than one second from the reference, contact your Swagelok representative.

Series 5/10/20 Weld Head Disassembly and Cleaning

This section describes the procedures necessary for disassembling the weld head and rotor.

Weld Head

To disassemble the weld head, follow these steps:

1. Blow any loose material from the weld head assembly with clean, low-pressure air.

2. Remove the four screws, locking ring, and locking ring plate. See Figure 6-6.

3. Remove the work extension screw with lock washer, and the work extension. Inspect the work extension for pitting, wear, or damage. See Figure 6-7.

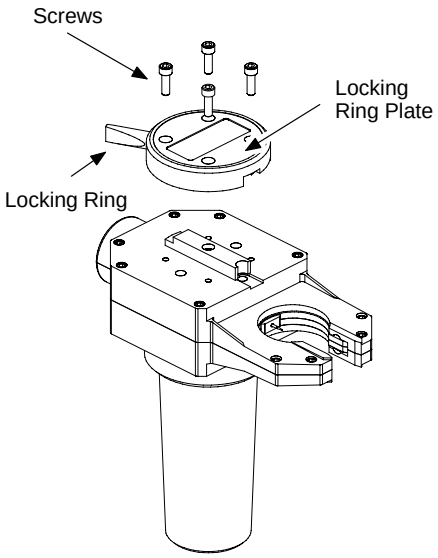


Figure 6-6 Removing the Locking Ring and Locking Ring Plate

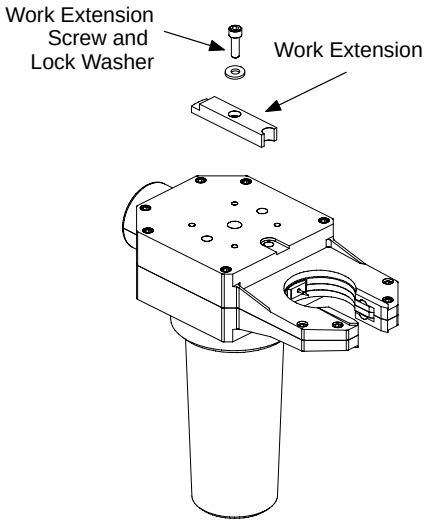


Figure 6-7 Removing the Work Extension

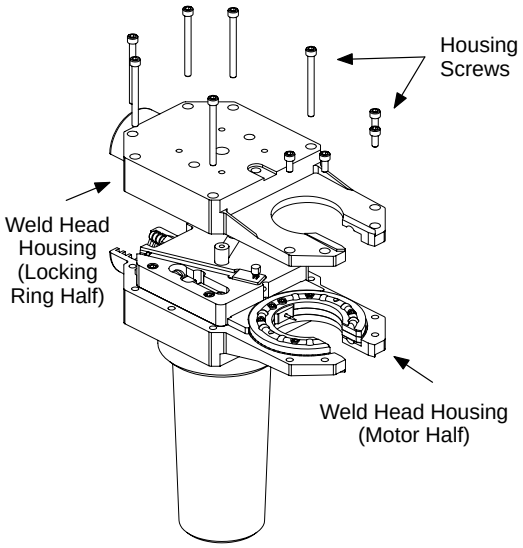


Figure 6-8 Removing the Locking Ring Half of the Weld Head Housing

4. Remove the weld head housing screws from the housing. Using a slight rocking motion, carefully separate the locking ring half of the weld head housing from the motor half. See Figure 6-8.

   Take care when separating the weld head housing so that internal components such as the safety interlock sensor or wiring are not damaged. See Figure 6-11.

5. Remove the rotor from the motor half of the weld head housing. See Figure 6-9.

6. Carefully lift the power block subassembly out of the motor half of the weld head housing. See Figure 6-10.

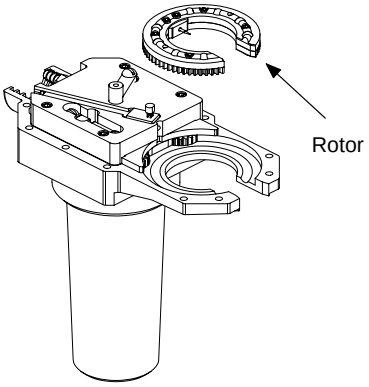


Figure 6-9 Removing the Rotor

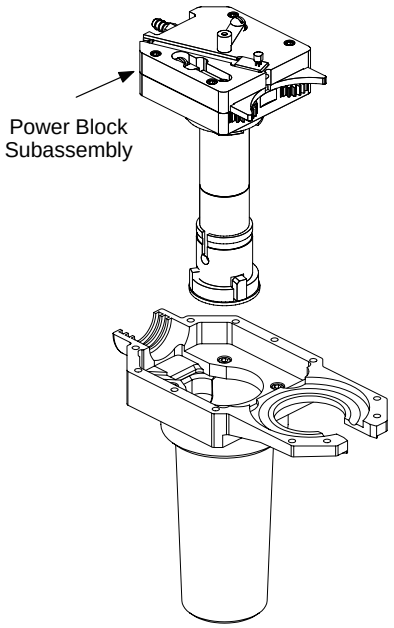


Figure 6-10 Removing the Power Block Subassembly

7. Examine the brush. See Figure 6-11.

   Inspect and clean the brush using the following steps:

   a. Check the brush for excessive wear.

   b. Ensure the brush has a groove. Replace the brush if the groove is not present by referring to the appropriate motor and power block assembly drawing in Appendix F, *Part Drawings*.

   c. Remove any oxidation from the brush with a fine-grit abrasive pad.

8. Blow any loose material from the power block assembly with clean, low-pressure air.

9. Ensure that the two power strap screws are tight. See Figure 6-12.

10. Ensure that the work plate screw is tight and free from excessive oxidation. See Figure 6-13. Clean the work plate with a fine-grit abrasive pad if necessary.

11. Inspect the gears for wear and replace if damaged by referring to the appropriate motor and power block assembly drawing in Appendix F, *Part Drawings*.

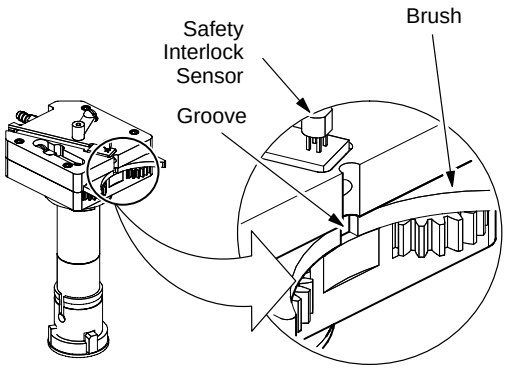


Figure 6-11 Inspecting the Brush

Caution!

Do not damage the safety interlock sensor while cleaning the brush. See Figure 6-11.

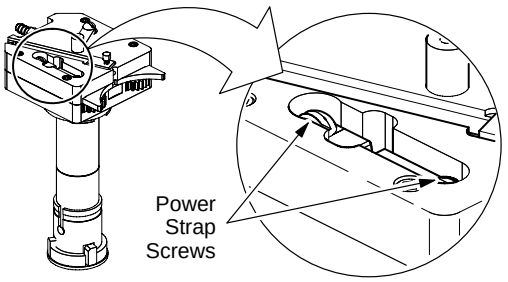


Figure 6-12 Inspecting the Power Strap Screws

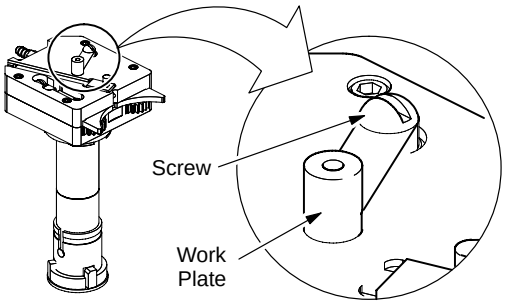


Figure 6-13 Inspecting the Work Plate and Screws

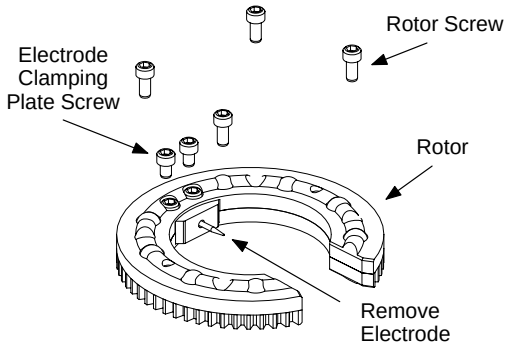


Figure 6-14 Removing the Rotor and Electrode Clamping Plate Screws

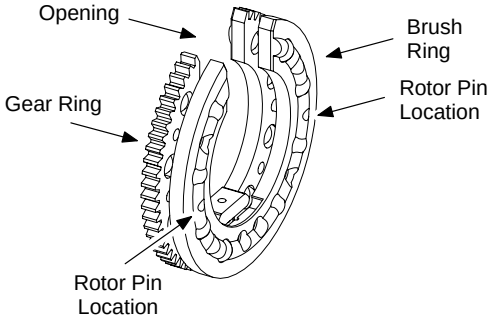


Figure 6-15 Placing the Rotor on the Work Surface

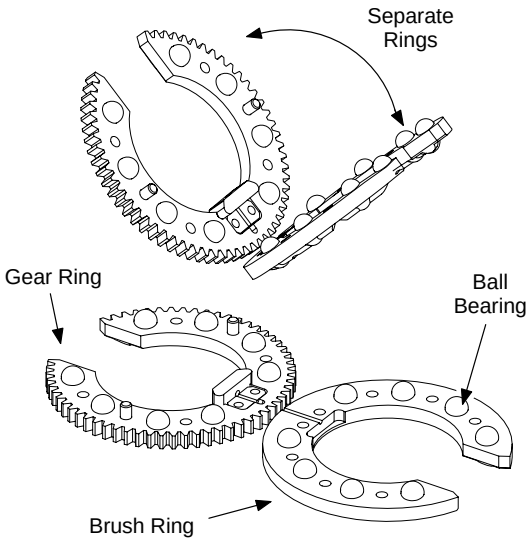


Figure 6-16 Separating the Gear Ring from the Brush Ring

Caution!

Do not use a flammable liquid to clean the ball bearings.

Rotor

To disassemble the rotor, follow these steps:

1. Remove the rotor screws and the electrode clamping plate screws from the rotor. Remove the electrode from the ceramic insert. See Figure 6-14.

2. Place the rotor on a clean, dry surface with the rotor opening facing up. Separate the gear ring from the brush ring enough to clear the two rotor pins. See Figure 6-15.

3. Completely separate the gear ring from the brush ring as shown in Figure 6-16. Lay the rings flat on the work surface.

4. Remove the ball bearings from the gear and brush rings. See Figure 6-16.

5. Inspect the ball bearings for wear and damage. Replace if necessary.

6. If the ball bearings are dirty, clean them with a mild solvent or cleaning solution. Dry the balls thoroughly.

7. Remove the ceramic insert. See Figure 6-17.

8. Inspect the ceramic insert. If it has carbon or other deposits, clean it with a fine-grit abrasive pad or soft nylon brush.

9. Remove the electrode clamping plate. Clean it with a fine-grit abrasive pad. See Figure 6-18.

10. Inspect the brush and gear rings for dirt or other deposits. Clean the rings with a fine-grit abrasive pad or soft stainless steel wire brush.

11. Dry all parts with clean, low-pressure air before reassembly.

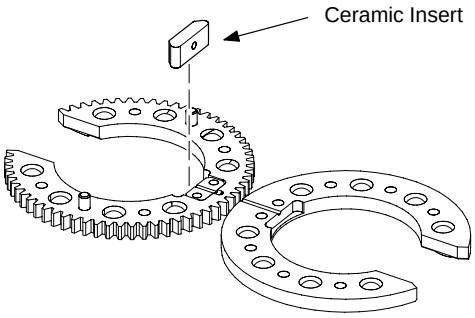


Figure 6-17 Removing the Ceramic Insert

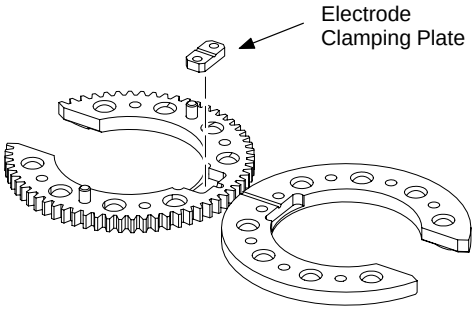


Figure 6-18 Removing the Electrode Clamping Plate

Series 5/10/20 Weld Head Assembly

Assembly of the weld head and rotor is the reverse of the disassembly procedures.

To assemble the weld head, follow these steps:

1. Complete the steps in reverse order in the rotor disassembly procedure on page 6-8.

2. Complete the steps in reverse order in the weld head disassembly procedure on page 6-5.

Caution!

Do not pinch any internal wiring or damage the safety interlock sensor during reassembly.

WARNING!

Disconnect the weld head from the power supply before performing the adjustment and maintenance procedures.

Caution!

Do not use any lubricants inside the weld head.

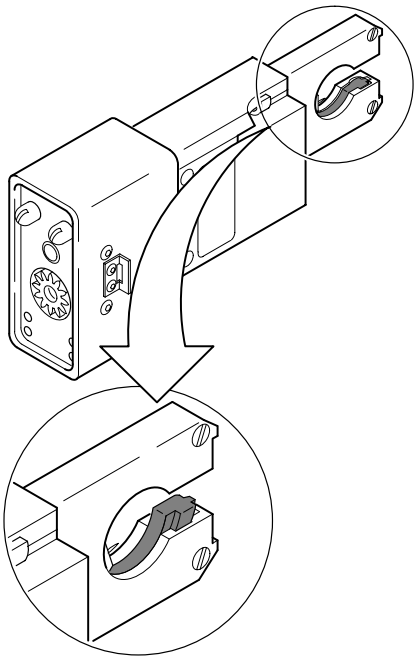


Figure 6-19 Inspect Exposed Surfaces of the Weld Head

Micro Weld Heads

Perform weld head maintenance daily and every 8 hours of welding time. If desired, maintenance may be performed before the 8-hour interval.

Daily Maintenance

At the start of each work day:

1. Inspect the micro weld head for cleanliness, focusing attention on the rotor area. See Figure 6-19.

2. Press **STOP/RESET**. Check the rotor for smooth rotation. If the rotation is erratic or noisy, disassemble the micro weld head and clean the rotor, idler gears, and brush. See page 6-12, “Series 4 Micro Weld Head Disassembly and Cleaning” or page 6-13, “Series 8 Micro Weld Head Disassembly and Cleaning.”

At the end of each work day:

1. Remove dirt, carbon, and vapor deposits from the weld head with a clean, soft cloth and a solvent such as alcohol. See Figure 6-19.

2. Store the micro weld head in a clean, dry place.

Eight-Hour Maintenance

Clean the motor module and weld head after every 8 hours of welding time.

Caution!

Do not clamp the motor module in a vise while cleaning.

Motor Module

1. Disconnect the weld head from the motor module.
2. Clean the motor module power lug sockets with the provided stainless steel brush. See Figure 6-20.
3. Carefully remove any obstructions from the purge port. See Figure 6-20.
4. Clean the two power lugs on the weld head with the provided stainless steel wire brush. See Figure 6-21.

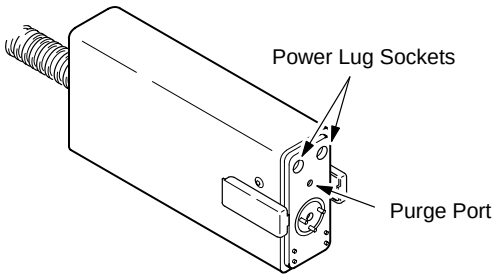


Figure 6-20 Cleaning the Power Lug Sockets and the Purge Port

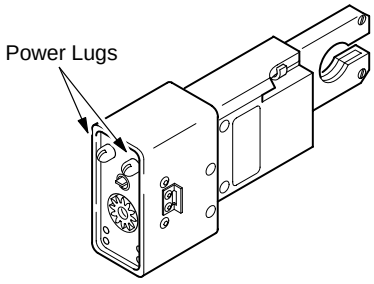


Figure 6-21 Cleaning the Weld Head Power Lugs

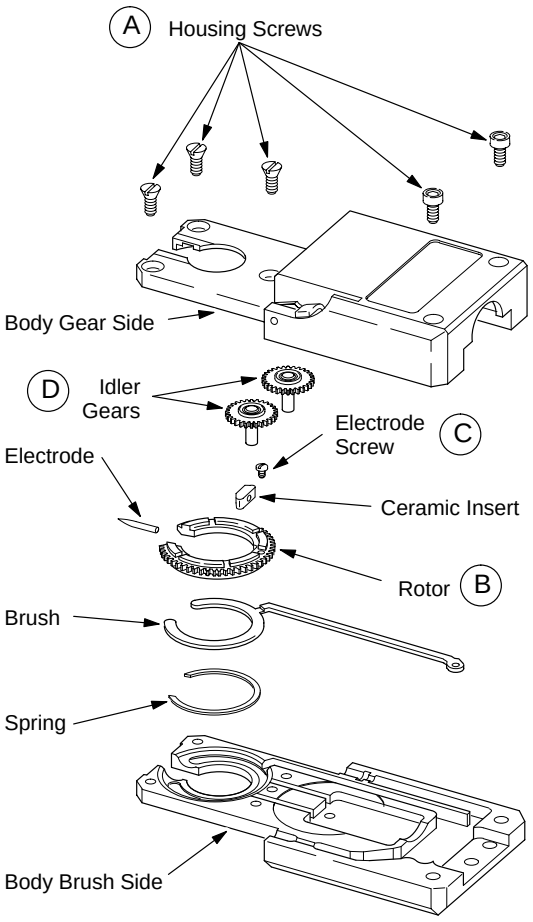


Figure 6-22 Removing Series 4 Micro Weld Head Components for Cleaning

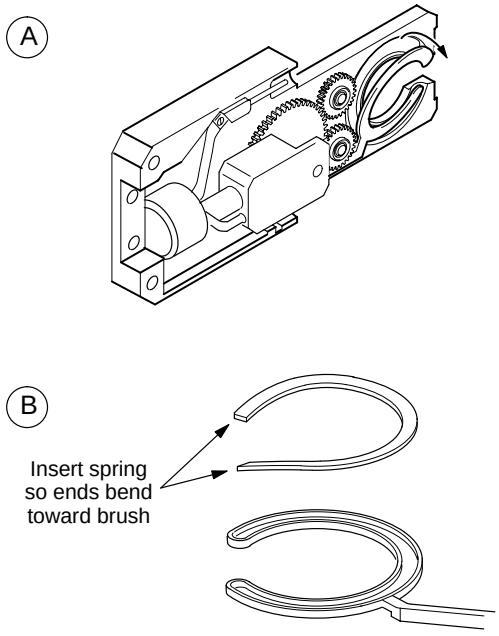


Figure 6-23 Lifting the Weld Head Brush for Cleaning

Series 4 Micro Weld Head Disassembly and Cleaning

Use the following instructions to disassemble the micro weld head for cleaning. Refer to the exploded view in Figure 6-22 for part references.

1. Lay the micro weld head down on a clean, dry surface with the model and serial numbers facing up.
2. Remove the five screws from the weld head housing. See Figure 6-22(A).
3. Rock the housing gently to loosen it from the rest of the assembly. Lift and remove the housing.
4. Remove the rotor by lifting it clear of the lower portion of the micro weld head housing. See Figure 6-22(B).
5. Loosen the electrode clamping screw, then remove the electrode and ceramic insert. See Figure 6-22(C).
6. Clean the rotor with the provided stainless steel wire brush.
7. Clean the ceramic insert with the provided nylon brush.
8. Remove and inspect the two idler gears for damage. Replace if necessary. See Figure 6-22(D).
9. Clean the two idler gears with a solvent and a soft cloth.
10. See Figure 6-23(A). Hold the micro weld head as shown. Gently lift the brush from the side noted in the figure and rotate it outward a few degrees.
11. Note the position of the spring in the groove in the weld head brush. The spring ends bend toward the brush when the spring lays in the groove. Remove the spring. See Figure 6-23(B).
12. Clean any oxide deposits from the weld head brush with the provided stainless steel wire brush.
13. Inspect all other weld head components and clean any that are dirty. Blow any loose dirt from the weld head with clean, dry, low-pressure air.

Series 8 Micro Weld Head Disassembly and Cleaning

Use the following instructions to disassemble the micro weld head for cleaning. See Figure 6-24 and Figure 6-25 for part references.

1. Remove the two screws securing the latch bracket and remove it from the weld head. See Figure 6-24.
2. Lay the micro weld head down on a clean, dry surface with the model and serial numbers facing up.
3. Remove the seven screws from the weld head housing. See Figure 6-25(A).
4. Rock the housing gently to loosen it from the rest of the assembly. Lift and remove the housing.
5. Remove the rotor by lifting it clear of the lower portion of the micro weld head housing. See Figure 6-25(B).
6. Loosen the electrode clamping screw, then remove the electrode and ceramic insert. See Figure 6-25(C).
7. Clean the rotor with the provided stainless steel wire brush.
8. Clean the ceramic insert with the provided nylon brush.
9. Remove and inspect the four idler gears for damage. Replace if necessary. See Figure 6-25(D).
10. Clean the idler gears with a solvent and a soft cloth.

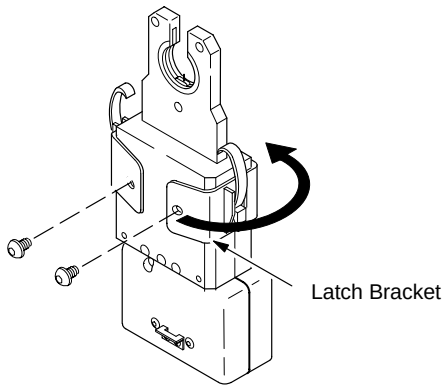


Figure 6-24 Removing Series 8 Micro Weld Head Latch Bracket

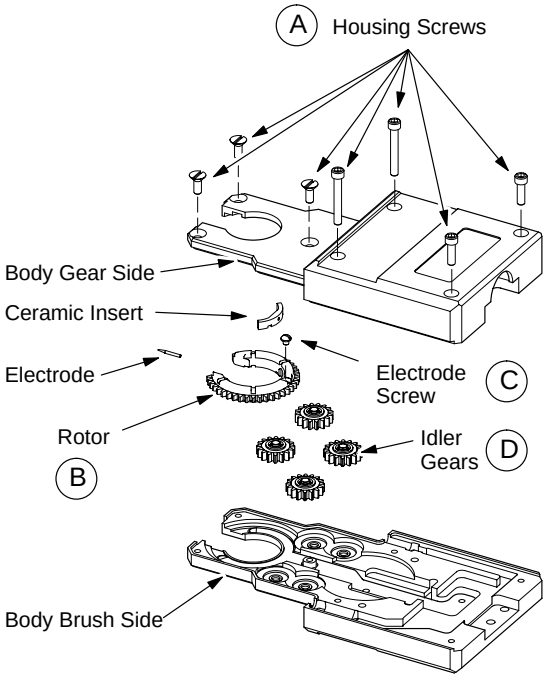


Figure 6-25 Removing Series 8 Micro Weld Head Components for Cleaning

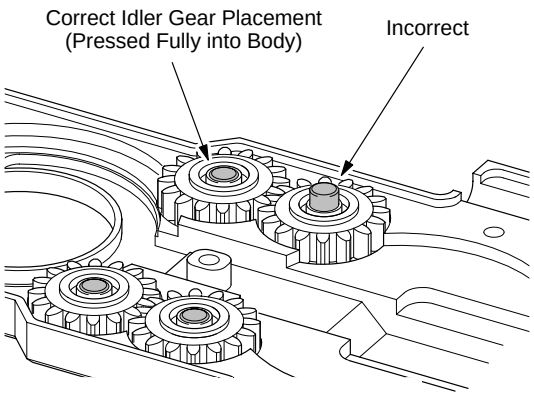


Figure 6-26 Correct Placement of Idler Gear in Micro Weld Head Housing

11. Replace the idler gears in the micro weld head housing. Verify the idler gear axle is pressed into the body. See Figure 6-26.

12. Clean any oxide deposits from the exposed surface of the weld head brush with the provided stainless steel wire brush.

13. Verify that the spring under the weld head brush is not exposed. See Figure 6-27. If necessary, reposition the spring under the weld head brush.

14. Inspect all other weld head components and clean any that are dirty. Blow any loose dirt from the weld head with clean, dry, low-pressure air.

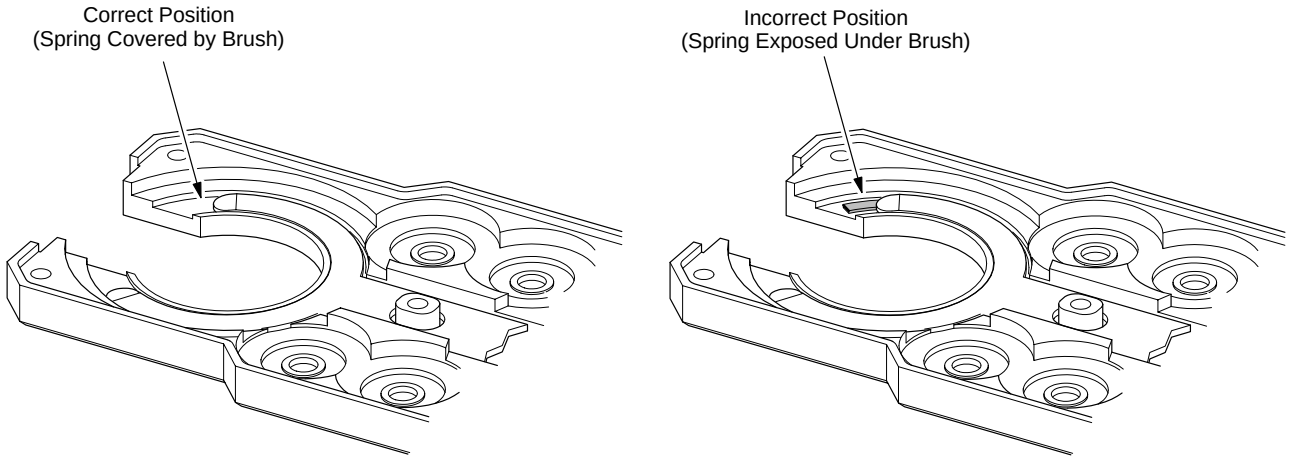


Figure 6-27 Spring Position

Micro Weld Head Assembly

Caution!

Do not pinch the internal wiring during reassembly of the micro weld head.

Assemble the weld head by completing the steps in the appropriate weld head disassembly procedure in reverse order.

Be sure to properly seat the brush spring during reassembly. See Figure 6-23(B) or Figure 6-27. If the spring is not seated properly, the rotor will not move. After reassembly, check the rotor for smooth motion by turning the drive gear by hand.

Power Supply

WARNING!

The user should not service the power supply.

The power supply has no internal serviceable parts and should not be disassembled.

Fuse Inspection and Replacement

Note: *The fuse can be checked with an ohmmeter.*

A 20 A (110 V (ac) system) or a 10 A (220 V (ac) system) ceramic fuse is on the rear panel of the power supply. A blown fuse does not permit an arc to start.

To inspect the fuse:

1. Turn off the power supply. See Figure 6-28.
2. Unplug the power cord.

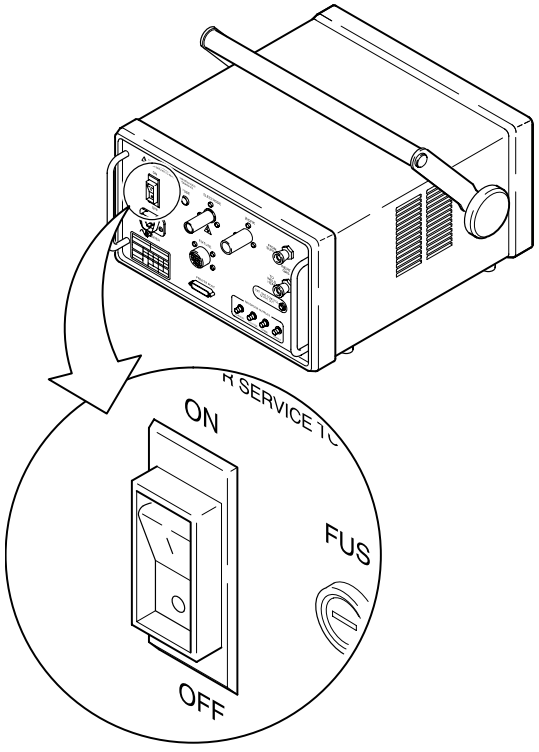


Figure 6-28 Power Supply Circuit Breaker in the OFF position

3. Inspect the fuse and fuse cap:
   a. Unscrew the fuse cap using a flat blade screwdriver. See Figure 6-29.
   b. Inspect the fuse cap for damage (overheating, burning, etc.). Replace the cap if necessary.
   c. Using an ohmmeter, check the continuity of the fuse. If it is blown, replace it with a fuse of the same type and rating.
4. Turn on the power supply.

Caution!

Use only insulated pliers to remove fuse.

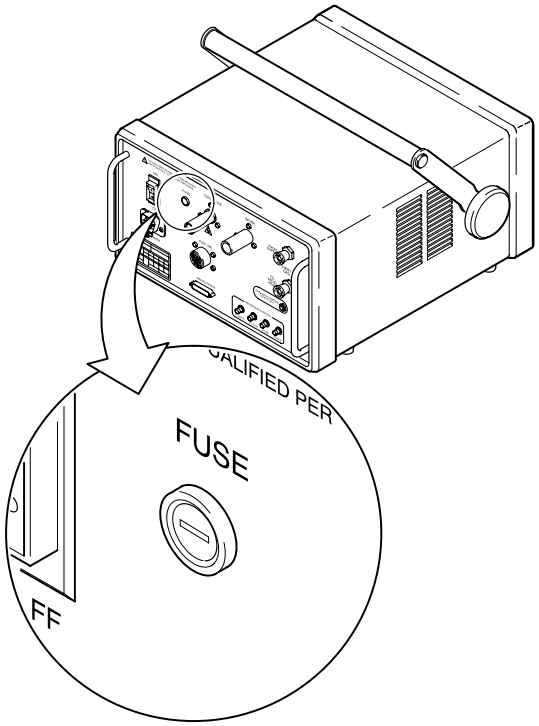


Figure 6-29 Ceramic Fuse Location

Section 7
Troubleshooting

Introduction

This section contains troubleshooting charts to assist you if a problem is encountered. Information is included for both hardware and weld process problems. This section contains troubleshooting guidelines for

- power supply
- weld head
- electrode
- fixture block
- welding process.

Swagelok Welding System (SWS) Repair Procedure

In some cases, the stated remedy to a problem listed in the charts may be “Call for service.” If so, contact your Swagelok representative for over-the-phone troubleshooting.

Be prepared to give the following information to the Swagelok representative:

- the serial number and model number of the equipment involved
- complete description of the application the product is being used in
- detailed description of the symptom

Provide complete details of any problem encountered to your Swagelok representative. Good information helps identify the exact problem and expedite the solution. This applies to problems that are handled over the phone or those that require the unit to be returned for repair. The result is faster repair times and more assurance that the repair meets with your approval.

Make the Swagelok representative aware if backup equipment is needed to temporarily replace the equipment being returned for repair.

Repair/Replacement Instructions

Certain remedies require a component, such as a weld head, to be disassembled, cleaned, or replaced. Section 6, *Maintenance*, contains user maintenance procedures. If in doubt about a procedure, call your Swagelok representative.

Power Supply

Symptom	Cause	Remedy
Front panel current/voltage digital displays are blank.	The circuit breaker is off.	Turn on circuit breaker.
	The power supply line cord is not plugged in.	Plug power cord into the wall outlet.
	STOP/RESET has been pushed with no weld head connected.	Press **STOP/RESET** again.
The replaced or new ceramic fuse fails immediately when power is turned on.	Internal component failure	Call for service.
Power supply fan does not operate.	Internal component failure	Call for service.
A status indicator light does not function.	Burnt out indicator light	Use test mode described in Section 3, *Operation,* to isolate the problem. Call for service if the light is faulty.
	Internal component failure	
Pushbutton does not function.	Dirty electrical contacts	Use test mode described in Section 3, *Operation,* to verify switch operation. Call for service if the pushbutton switch is faulty.
	Switch failure	

Note: *The circuit breaker is of the type that must be reset if it trips. Reset the breaker by setting it to the OFF position before turning it on.*

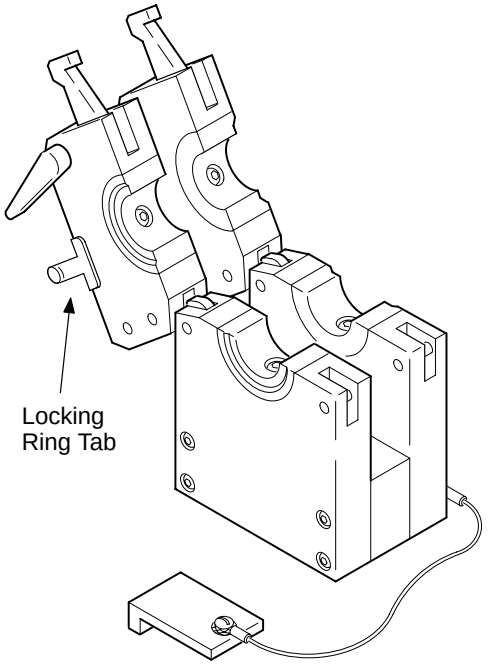


Figure 7-1 Fixture Block Locking Ring Tab

Symptom	Cause	Remedy
Fixture indicator fails to turn off when the weld head is connected to a fixture block.	The weld head is not fully engaged into fixture block.	Reattach the fixture block to the weld head.
	The fixture block locking ring tab is dirty. See Figure 7-1.	Clean the locking ring tab. Make sure all surfaces are shiny.
	The rear panel fixture connector is not fully engaged.	Check that the fixture connector is seated and its collar is tight.

Weld Head

Symptom	Cause	Remedy
Rotor does not return to the home position.	Fixture connector is not fully engaged.	Check that the fixture connector is seated and its collar is tight.
	Rotor is not at the home position when the power supply is turned on.	Use **ROTOR JOG** to move the rotor to the home position, then cycle power off and on.
	Dirty home sensor.	Disassemble the weld head and check the home sensor for dirt. See the appropriate motor and power block assembly drawing in Appendix F. Use compressed air to blow off debris.
	Rotor gear ring is misaligned with secondary gears.	Realign the rotor with the weld head opening. See Section 6, *Maintenance*.
	Fixture connector has broken or damaged pins/wires.	Call for service.
	Home sensor is damaged or misaligned.	Call for service.
Rotor squeaks when turning.	Dirty or worn weld head body halves.	Disassemble the weld head and clean/ replace components.
	Gear bearings worn or dirty.	Clean or replace bearing assemblies as needed.
	Dirty ball bearings in rotor.	Disassemble rotor and clean or replace ball bearings as needed.
Rotor does not move or makes a clicking noise when turning.	Debris on gears.	Check for weld spatter or debris on gears.
	Loose drive clip in the micro weld head.	Check and replace drive clip if needed. See the appropriate micro weld head assembly drawing in Appendix F.
	Brush spring is installed incorrectly in micro weld head.	Install the brush spring in the correct orientation. See Section 6, *Maintenance*.
	Bent motor shaft.	Call for service.

Symptom	Cause	Remedy
Erratic rotor rotation/ speed control.	Weld spatter on gears.	Inspect the rotor primary, secondary, and drive gear(s) for damage. Replace damaged gears.
	Arcing damage on rotor gear teeth.	Inspect rotor and replace if damaged.
	Dirty weld head, debris on encoder sensor or encoder wheel.	Disassemble the weld head and clean thoroughly.
	Encoder wheel slips on motor shaft.	Call for service.
	“Sticky” rotary switches	Use test mode to isolate the problem. Call for service.
	Fixture connector has broken wire.	Call for service.
Arc damage on rotor gear.	Arcing from rotor.	Clean gear, or replace if necessary.
Damage to weld head body halves.	Arcing	Disassemble the weld head. Clean/replace parts as needed. Follow the recommended maintenance schedule outlined in Section 6, *Maintenance*.
	Excessive heat from welding.	Check weld procedure guideline. Use a larger weld head, allow a cooling period between welds, or allow continuous shielding gas flow when welding.
	Weld head was dropped	Check for damage and replace parts as necessary. Check rotor for smooth operation. Call for service if damage is severe.

Electrode

Symptom	Cause	Remedy
Material found on the electrode tip.	Electrode touched the weld puddle.	Replace electrode and check arc gap setting. Check work pieces for out of roundness.
	Weld puddle protrusion.	Check internal purge gas flow rate for excessive back pressure.
	Weld head is not properly attached to the fixture block.	Reattach the weld head to fixture block. Engage the weld head locking lever.
Oxidation film on the electrode.	Insufficient shielding gas.	Increase shielding gas flow rate.
	Insufficient post purge time.	Increase post purge time.
	Partially blocked or cut shielding gas line.	Check for leaks and/or blockage. Replace purge lines if needed.
	O-ring missing between the weld head and motor module. Micro Weld Head Only	Check and install O-ring if necessary.
	Shielding gas line disconnected inside weld head.	Disassemble weld head and reconnect the line.
Bent or broken electrodes.	Electrode was not secured in the rotor.	Replace the electrode. Tighten electrode clamping screws.
	Weld head not correctly attached to the fixture block.	Replace the electrode. Reattach the weld head to the fixture block. Engage the weld head locking lever.
	Incorrect arc gap setting.	Check the length of the electrode and replace it. Reset arc gap.
Melted electrode.	No shielding gas.	Check for shielding gas flow and set the proper flow rate.

Fixture Block

Symptom	Cause	Remedy
When closing the fixture block side plate, the latch does not lock.	The latch is not inserted into the fixture block side plate completely.	Reinsert the latch into the side plate until it rests against the latch pin.
	Bent latch.	Replace latch.
	Oversized tubing.	Replace fitting/tubing with the correct size.
	Wrong size collets.	Replace with the correct size collet.
	Hinge worn out.	Replace the hinge and dowel pins.
	Worn out latch cam.	Replace the latch cam.
The latch does not fit into the bottom part of the fixture block side plate.	A burr is in the slot or on the latch.	Use a fine file to remove burrs.
	The latch is bent or damaged.	Remove the latch and replace all damaged parts.
	The hinge is bent or damaged.	Remove the hinge and replace all damaged parts.
The fixture block does not fit onto the weld head.	The arc gap is incorrect.	Reset arc gap according to the Weld Procedure Guideline.
	The locking ring tab is broken or damaged.	Replace the locking ring tab.
	The weld head is incorrectly assembled.	Reassemble using the instructions found in Section 6, *Maintenance*.
	Arc damage on fixture.	Clean fixture. Remove and replace any damaged parts.

Welding Process

Symptom	Cause	Remedy
Arc fails to start.	Blown ceramic power supply fuse.	Replace the ceramic power supply fuse with one of the same type and rating.
	Fuse not seated in fuse holder properly or fuse spring is missing.	Insert fuse properly. Replace fuse spring if necessary.
	Incorrect arc gap setting.	Reset the arc gap with the arc gap gage.
	Either **ARC START**, **DURATION**, or both settings are incorrect.	Refer to the weld procedure guideline established for the job. Adjust start and duration settings as necessary.
	Excessive purge gas flow.	Reduce flow to the value shown on the weld procedure guideline.
	Insufficient shielding gas flow or contaminated shielding gas.	Check the shielding gas source for low pressure. Check gas lines for leaks. Change to a different gas source or change oxygen removal filter.
	Electrode in poor condition.	Replace electrode.
	Damaged electrical connections in the weld head.	Weld head needs repair. Call for service.
	Poor contact between locking ring tab and ground extension.	Inspect and clean all contact surfaces.
	Poor contact between rotor and brush.	Inspect and clean all contact surfaces.
	Poor contact between tubing, collet, and fixture block.	Inspect and clean all contact surfaces.
	Arc start power set to zero.	Set Arc Start power (menu item 23) to one. See page 3-19 for details.

Note: *All fuses should be rated at 250 V (ac). 110 V (ac) power supplies use a 20 A fuse (1/4 in. x 1 1/4 in.), 220 V units use a 10 A fuse (5 mm x 20 mm).*

Note: *The ceramic fuse is located on the rear panel of the power supply. See Figure 7-2.*

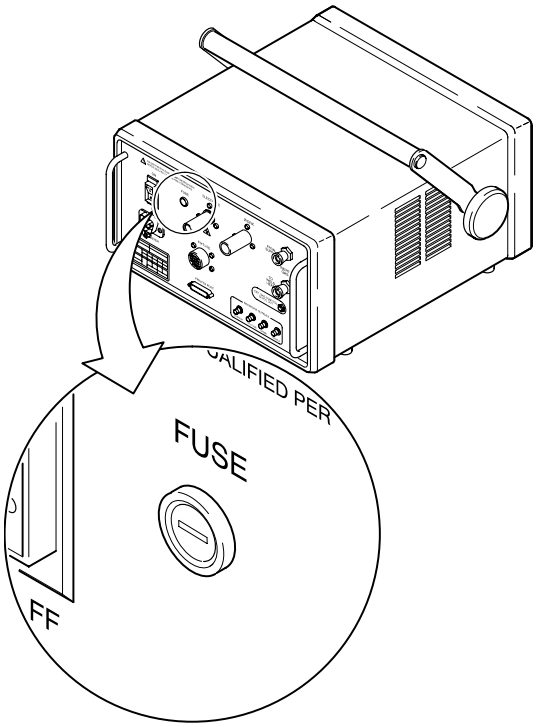


Figure 7-2 Ceramic Fuse Location

Symptom	Cause	Remedy
Displayed average current value is much higher or lower than the expected level shown in the weld procedure guideline.	Incorrect weld parameter(s) entered on the rotary switches.	Verify rotary switch settings match the guideline and adjust if necessary. Refer to the flowchart in Figure 5-20. Adjust weld parameters as necessary using the weld procedure guideline.
	Rotary switch settings are not giving the expected output.	Use test mode described in Section 3, *Operation*, to verify proper switch operation. Call for service if switches are faulty.
Voltage fluctuations during the weld cycle exceeding 2 V.	Weld head not seated properly into the fixture block.	Reattach the weld head to the fixture block. Engage the weld head locking lever.
	Work pieces are out of round.	Replace work pieces if out of standard specifications.
	Insufficient shielding gas flow or contaminated shielding gas.	Check the shielding gas source for low pressure. Check gas lines for leaks. Change to a different gas source or change oxygen removal filter.
Outside diameter discoloration.	Insufficient shielding gas flow.	Increases shielding gas flow rate and prepurge time.
	Impurities in the gas supply.	Check gas lines for leaks. Change to a different gas source or change oxygen removal filter.
	Wrong type of purge gas used.	Change to correct type of purge gas.
	Contamination on work pieces.	Clean the work pieces before welding.
	Contaminants in the weld head and purge lines.	Increase prepurge time. Check the gas source for low pressure.
	Shielding gas line disconnected from the power supply.	Reconnect gas line.

Symptom	Cause	Remedy
Inside diameter discoloration.	Insufficient internal purge gas.	Increase internal purge gas flow rate and prepurge time.
	Contaminants in the purge line.	Increase prepurge time. Check the gas source for low pressure.
	Migration of oxygen from the internal purge gas exit port of the work pieces to the weld joint.	Reduce exit port size with a purge restrictor. See Note.
	Wrong type of purge gas used.	Change to correct type of purge gas.
	Contamination on work pieces.	Clean the work pieces before welding.
	Nicks/cuts in the internal purge gas line.	Replace gas line.
Hole in the weld bead.	Incorrect arc gap.	Reset the arc gap with the arc gap gage.
	Excessive internal purge gas back pressure or surge.	Remove any obstruction of the internal purge gas flow or reduce the flow.
	Improper tube preparation.	Inspect and reface tubing.
	Incorrect weld parameter setting. (impulse)	Check and adjust the weld parameter settings.
	Loss of shield gas flow.	Check the shielding gas source for low pressure. Check gas lines for leaks. Change to a different gas source or change oxygen removal filter.

Note: *The purge restrictor must be of adequate size to prevent excessive inside diameter back pressure.*

Symptom	Cause	Remedy
Concave weld puddle.	Excessive heat input.	Compare the material, wall thickness and outside diameter size of the components you are welding to the weld procedure guideline being used. Verify rotary switch settings match the guideline and adjust if necessary. Refer to the flow chart in Figure 5-17. Adjust weld parameters as necessary.
	Insufficient inside diameter purge gas flow.	Compare flowmeter settings to the weld procedure guideline being used. Adjust if necessary.

Symptom	Cause	Remedy
Incomplete inside diameter penetration.	Insufficient heat input.	Compare the power supply rotary switch settings to the weld procedure guideline being used. Refer to the flowchart in Figure 5-20. Adjust weld parameters as necessary.
	Incorrect weld procedure guideline.	Compare the material wall thickness and outside diameter size of the work pieces being welded to the weld procedure guideline being used. Refer to the flowchart in Figure 5-20. Adjust weld parameters as necessary.
	Incorrect arc gap.	Reset the arc gap with the arc gap gage.
	Tip of electrode is worn or ground improperly.	Change the electrode.
	Inconsistent heats of materials or changes in material chemistry.	Verify consistency of material with material supplier. Refer to the flowchart in Figure 5-20. Adjust weld parameters as necessary.
	Weld joint is off-center or misaligned.	Inspect the entire weld joint in the fixture block prior to welding.
After welding, the tubing/fitting assembly is not straight.	The end surfaces of the work pieces being welded are not perpendicular to their center axis.	Prepare the work piece weld ends properly. See page 3-28 in this user's manual.
	The fixture block side plate screws are not tight.	Tighten screws as needed.
After welding, the fitting/tubing joint is still visible.	The fitting/tubing was not centered properly.	Center fitting/tubing.
	The electrode is bent or was not properly installed.	Inspect the electrode and replace if necessary. Reset the arc gap with the arc gap gage.

Appendix A
Glossary

Arc

The flow of electrical current between an anode and cathode. In welding, the flow of current between an electrode and the work.

Arc Gap

The distance between the electrode and the work.

Arc Gap Gage

The gage used to set the arc gap in the weld head rotor.

Arc Radiant Energy

The ultra-violet light emitted from the welding arc.

Arc Start

The period of the welding cycle following prepurge. During this short period of time, approximately 0.01 second, high voltage is applied between the electrode and workpiece, initiating the arc. The only control of this period is with arc start power, Code 23 in program mode.

Arc Welding

A type of welding process that uses an electrical arc as a source of heat to melt and join metals.

Arcing

A condition in welding where the arc follows another path instead of from the the electrode to the work. This can cause damage to the weld head and fixturing components.

Argon

An inert monatomic gas used as a shielding and purge gas for gas tungsten arc welding.

Autogenous

In orbital welding, autogenous describes the process of welding two parts together using the fusion process without the use of filler material.

Automatic Welding

A welding process in which all of the parameters are controlled by the welding machine during the weld cycle. The process may or may not perform the loading and unloading of the work pieces.

Average Current

In pulse welding, high current is maintained for some fraction of each output cycle and low current is maintained for the remainder of the cycle. The average current is the sum of these fractional components that occur during each cycle.

Backing Gas

The gas used at the back of a weld joint or within a tube or vessel to prevent oxidation and undercut.

Butt Weld

A weld joint where two work pieces are welded together with their long axes concentric and in-line. The joint can have various configurations, such as square groove, v-groove, j-groove, double v-groove, etc.

Centering Gage

Gage used to center the work pieces in the fixture block.

Ceramic Insert

A ceramic insulator used in the rotor to isolate the electrode from the weld head. The insert helps to prevent arcing.

Collet

A device used to hold the work pieces in the fixture. Collets are made to hold work pieces of various diameters and shapes.

Concavity

In welding, the condition where the weld profile extends below the outside surface of the work.

Data Logging

Collecting welding parameter data without regard to faults or alarms.

Data Monitoring

Collecting data and comparing it to preset conditions. Alarm triggering can be enabled if the data is outside normal limits.

Dedicated Line

An electrical service line used for only one device. The device is isolated from interference created by other equipment and can utilize the full current capacity of the line breaker.

Diagnostics

A built-in program that checks the function of the front panel controls and indicators of the SWS power supply. Errors are shown on the front panel digital displays.

Disable

An error condition created by a mis-programmed front panel rotary switch. The switch value is outside the safe operating range of the weld system. The SWS will not weld while a Disable condition exists.

Discontinuity

The characteristic of a weld bead marked by breaks or interruptions in the typical structure, causing a lack of homogeneity. A discontinuity is not necessarily a defect.

Downslope

The portion of the welding cycle when the weld current is decreased from the welding level to zero over a specific period of time. Downslope time is used to prevent weld bead cracking.

Drop Through

A condition where the weld puddle extends into the inside diameter of the weldment.

Duration

The period following arc start during which the arc stabilizes and the weld puddle develops. The current set on **ARC START** is maintained for the time set on **DURATION**. The rotor does not move during this period.

Electrode

A pointed cylindrical rod made from a nonconsumable, tungsten alloy which is used as a conductor for the arc in the GTAW process.

GTAW

An acronym for gas tungsten arc welding, the process used in the Swagelok Welding System (SWS).

Heat Input

The heat conducted into the weld during the weld cycle. It is generally expressed in Joules or kiloJoules.

Impulse (High Amps)

The maximum current level generated during the weld cycle. Also referred to as high amps.

Inclusion

A defect or discontinuity in the work material or weld that could become a site for stress or corrosion.

Internal Purge Gas

The gas used at the back of a weld joint or within a tube or vessel to prevent oxidation and undercut.

Jog

The term used when positioning the rotor with the Rotor Jog pushbutton before or after the weld cycle.

Joule

A unit of energy. One joule is equal to one ampere times one volt for one second. Also termed a watt-second.

Maintenance (Low Amps)

The minimum current level generated during the weld cycle. Also referred to as background current or low amps.

Misfire

An action that occurs when the arc fails to start or sustain itself.

Multiple Pass

A welding technique in which the rotor moves more than one revolution during the weld time. The technique is most helpful when fusion welding small diameter parts.

Orbital Welding

A welding technique used for tubing, pipes, etc. in which the arc rotates around the weld joint circumference.

Oxidation

Heat discoloration that occurs in the weld area caused by the presence of oxygen. It can vary in color and intensity based on the weld temperature and the amount of oxygen present. Oxidation can be detrimental to high purity systems and increase the chances of weld joint corrosion.

Ozone

A gas produced from the disassociation of oxygen in the presence of the electric arc.

Penetration

The term used to describe the depth of the weld. The common usage to describe the correct level of penetration for tube and pipe welds is “full penetration weld.” This means the weld has penetrated completely from the outside diameter to the inside diameter of the weld joint. There are no portions of the weld joint that are visibly unfused.

Plenum

A device that separates the fixture block side plates, providing space for the weld head and forming a chamber for the shielding gas.

Power Supply

The device that produces the electrical power for the welding process. The SWS power supply is a constant current power supply.

Pulse Rate

The rate at which the output current level is changed between the high (Impulse) and low (Maintenance) settings. The rate is expressed as pulses per second.

Pulse Weld

A weld current that varies between a high level and a low level at a specific rate. The technique reduces the heat input to the weld.

Pulse Width (% Impulse)

The percentage of time during one cycle that the weld current is at the Impulse (High Amps) level.

Purge Gas

The gas used at the back of a weld joint or within a tube or vessel to prevent oxidation and undercut.

Remote Pendant

A hand-held control device that allows remote operation of the SWS power supply.

Re-enforcement

The excess metal on the outside surface of the weld that extends above the surface of the work. It is sometimes referred to as the “crown” or “bead.”

Rotor

The device that holds the tungsten electrode and moves around the weld joint during orbital welding.

SCFH

The acronym for standard cubic feet per hour. This is the unit used to measure the flow rate of shielding and purge gases.

Shielding Gas

The gas used to shield the tungsten electrode and work pieces during the welding cycle. It also cools the weld head.

Single Level

A welding technique in which a single value of current is used during the weld cycle.

Single Pass

A welding technique in which the rotor moves one revolution during the weld time.

Socket

A type of weld joint.

Solenoid Bypass

An option that bypasses the internal gas solenoid in favor of a secondary valve. The secondary valve is controlled by the power supply.

Straight Polarity

The electrical configuration which makes the electrode the negative lead and the work the positive lead.

Travel Speed

The speed of the electrode as it passes over the weld joint, usually expressed in inches per minute or centimeters per second.

Tungsten

The material used to make the electrode. Tungsten is typically alloyed with rare earth metals to enhance its current carrying capacity.

UCI

An acronym used for universal collet insert, the exchangeable component used in the fixture block to hold the work pieces. The patented design inserts come in various sizes to match the outside diameter of the work pieces.

Watt

A unit of electrical power measurement. One ampere times one volt equals one watt.

Weld Coupon

A sample weld made for evaluation purposes. The weld is used for both visual and physical testing.

Weld Data Record

A printout, used for data recording purposes, listing weld parameter inputs, power supply outputs, and performance confirmation.

Weld Procedure Guideline

The term used to describe a custom set of weld parameter values used to program the SWS for a particular welding job. The parameter settings are based on the characteristics of the work and the SWS configuration. It is sometimes called the “weld schedule.”

Weld Pool Shift

A welding condition in which the weld puddle is displaced to one side of the weld joint due to differences in the active surface elements of the metals to be welded.

Weld Puddle

The portion of the weld that is molten.

Weld Time

The portion of the weld cycle in which the current is at the level needed to fully penetrate the weld joint. The current will pulse between Impulse and Maintenance levels.

Appendix B
Optional Equipment

This appendix lists the optional equipment available for your Swagelok Welding System (SWS). Contact your Swagelok representative for additional information on any listed option.

This section includes:

- SWS Remote Pendant
- weld head extension cables
- data logging/monitoring
- SWS Data Recording Printer.

SWS Remote Pendant

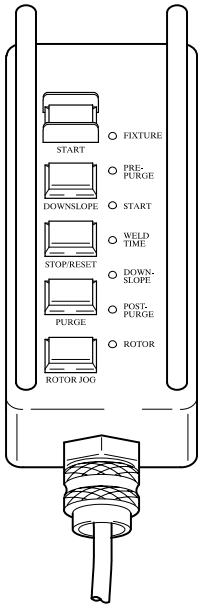


Figure B-1 Remote Pendant

See Figure B-1. The SWS Remote Pendant allows you to control the SWS operation from up to 25 ft away. The remote pendant contains the same pushbuttons and status indicator lights as the power supply front panel, with the exception of the **PRINT** pushbutton. Cable extensions are available to increase the overall length to 100 ft.

The unit is attached to the power supply via the connector labeled Remote on the front panel. See Figure B-2.

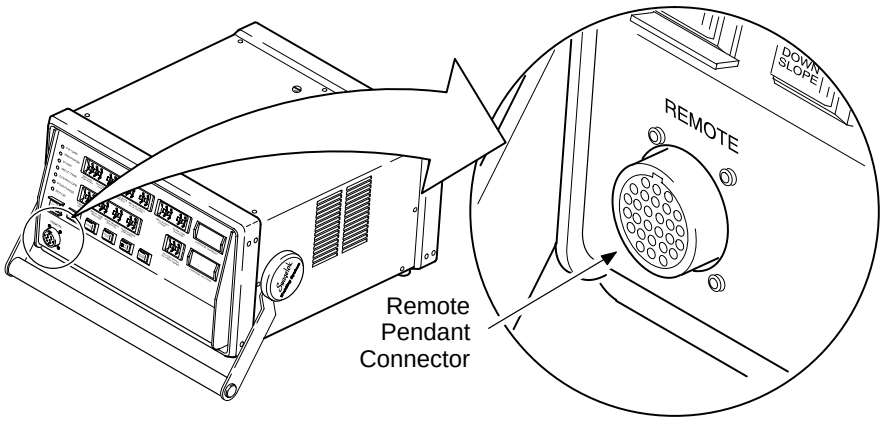


Figure B-2 Remote Pendant Connector

Weld Head Extension Cables

The weld head extension cables increase the distance from the power supply to the weld head up to a maximum of 50 ft, including the weld head cable. The extension cable is placed between the power supply and weld head.

Note: *When using an extension cable, increase the prepurge time by 1 second for each foot of extension cable.*

Install the extension cable as follows:

1. Turn off the power supply circuit breaker.
2. Disconnect the weld head from the power supply. Plug the weld head connectors into the end of the extension cable that will accept them.
3. Insert the connectors of the other end of the extension cable into the appropriate sockets on the power supply rear panel.
4. Turn on the power supply.
5. Locate the **STOP/RESET** and **PURGE** pushbuttons on the front panel. See Figure B-3.
6. Press **STOP/RESET** and check for rotor rotation. Press **STOP/RESET** again if the rotor is not at the home position.
7. Press **PURGE** and check for gas flow through the weld head. Allow the shielding gas to flow for at least 60 seconds to clear the gas lines of oxygen. Press **PURGE** again to stop the gas flow.

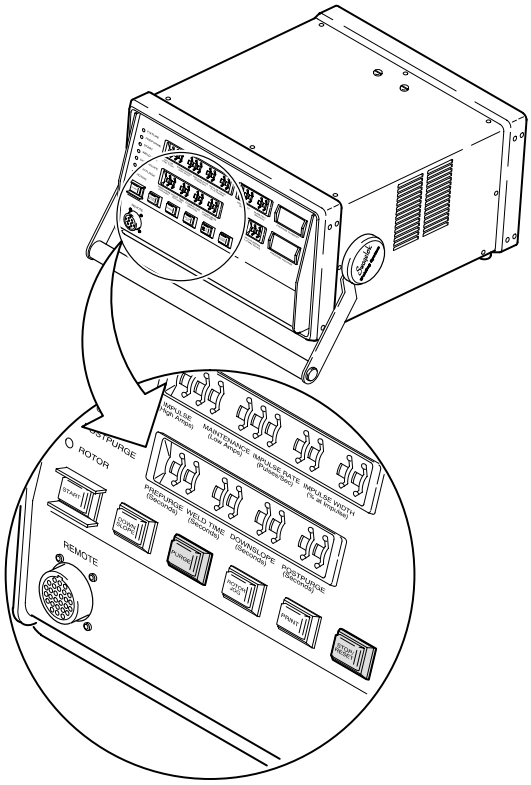


Figure B-3 Pushbutton Locations

Data Logging/Monitoring

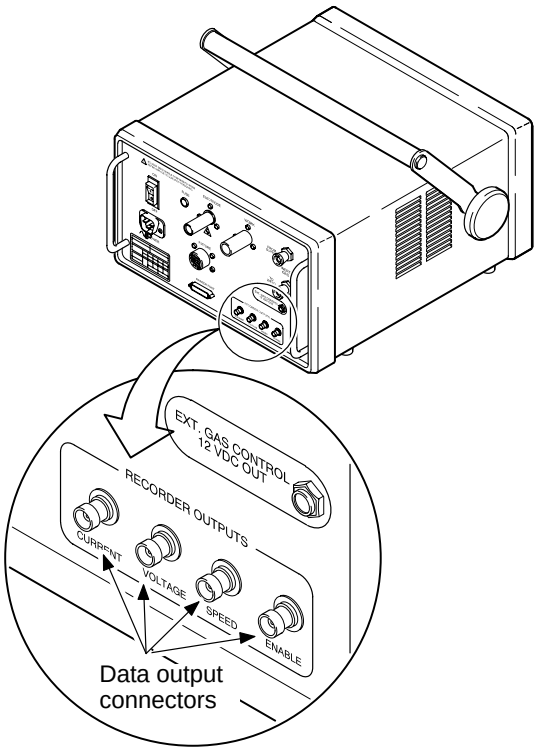


Figure B-4 Data Logging Outputs

The power supply has four Bayonetted-N Style connectors (BNC) on the lower portion of the rear panel that provide analog data outputs. The data outputs have a signal range from 0 V (dc) to 5 V (dc). See Figure B-4.

Connect a chart recorder or other recording device to these outputs to monitor the SWS during welding. The BNC connectors output the following signals:

- current
- voltage
- rotor travel speed
- enable

The current, voltage, and rotor speed outputs are used to monitor the performance of the SWS.

Table B-19 Data Output References

Output Function	0 V Reference	4 V Reference
current	0 A	100 A
voltage	0 V	20 V
travel speed	0% of max RPM	100% of max RPM

Note: *The data recorder must have high impedance inputs (greater than 1 MΩ).*

Enable is a control signal for the external recorder. Equipment with the capability to start and stop data recording can use this signal as the trigger to control the recording function.

The polarity of the enable signal is selectable. See Program Mode Operation in Section 3, *Operation*.

Note: *Variables such as material chemistry, weld end preparation, electrode condition, and shielding gas may also affect the weld quality. The user must decide how to use the information provided by this feature.*

The data from these outputs does not indicate whether the weld is acceptable, but instead provides a record of the equipment performance during the welding process. The data can be compared to the weld procedure guideline as a method of quality control.

Visual, mechanical, and other testing must also be done to verify the weld integrity. As with any connection, proper leak testing should be performed once the weld is completed.

When selecting data recording equipment, consider the accuracy of the printout required. The frequency response of a recorder determines its ability to respond to a signal change, which determines printout accuracy.

To record accurate data during the welding process, it is suggested that the data collecting device have a sampling rate ten times faster than the maximum weld impulse rate. If the sampling rate is not sufficient, the data is not recorded accurately. The SWS maximum pulse frequency is 99 pulses per second. This pulse rate suggests a minimum sample rate of 1000 samples per second. In addition to the sampling rate, the equipment must also have the capability to gather data over the longest programmed weld time, 198 seconds.

When an analog strip chart recorder is used, the 0 V (dc) to 5 V (dc) signals drive the strip chart pens. This type of recorder generally has limited memory and does not store data for future retrieval.

When the data must be captured and stored for future reference, digital recording equipment is used. This equipment converts the analog signals to data patterns that are stored to some device, such as a memory unit or a hard disk. The data can be recalled as needed and can be used for later analysis of the welding process.

Remember that data recording is just a method used to monitor the welding process and does not guarantee the quality of the weld.

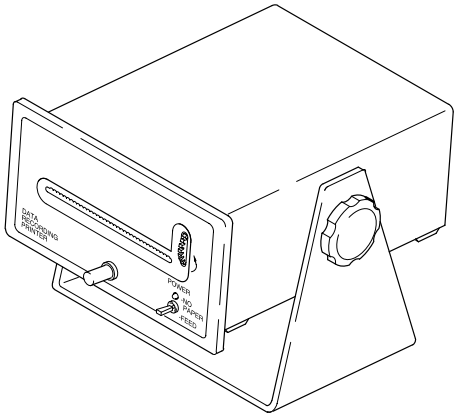


Figure B-5 CWS−DRP Data Recording Printer

Data Recording Printer

Introduction

The optional SWS Data Recording Printer is a small size thermal printer ideal for mobile use. See Figure B-5.

The printer is covered under the same warranty as the power supply.

Unpacking and Inspection

Carefully unpack and inspect the SWS printer and printer cable for any damage which may have occurred in shipping.

If the printer or cable is damaged, contact your Swagelok Representative.

Installation

The printer mounts on the top of the power supply. The printer requires a special interface cable (CWS-DRP-CABLE). The cable supplies both power and data to the printer. The standard cable length is 2 ft (61 cm). With an optional interface cable, the unit can be placed up to 25 ft away from the power supply.

Before operating your printer, do the following:

- Install the printer using the instructions provided in this section.
- Ensure that the printer mechanism and paper path are clear of any packing materials or foreign matter.

Note: *For optional cable lengths, add the cable length (6,12,or 25) to the part number as a suffix. For example, a 25 ft cable part number is CWS-DRP-CABLE-25.*

Caution!

Do not use a standard RS-232 printer cable to interface this printer.

Caution!

Do not operate the printer without paper. (Refer to section on paper loading.)

Load the Paper

1. If necessary, remove the interface cable from the rear of the printer. See Figure B-11.

2. Turn the latch counter-clockwise to release the printer body from the case. Remove the printer body from the case by pulling it forward. See Figure B-6.

3. Remove the paper roll spindle pin and used paper spindle.

4. Install the new roll of thermal paper and load the paper into the feed mechanism. See Figure B-7.

   a. Place the roll between the support brackets in the position so that the paper feeds from the top. Hold the paper roll so that the hole in the paper spindle is aligned with the holes in the support brackets.

   b. Fold about 1/2 in. of the leading edge of the paper back over itself so that folded portion is facing up.

   c. Insert the paper under the silver pin and under the top half of the paper sensor. Push the leading edge of the paper forward into the feed mechanism.

   d. Insert the paper spindle pin in through the paper spindle. Make sure the paper spindle pin is installed in the orientation shown in the figure.

   e. Advance the paper with the thumbwheel until it comes out of the front panel slot.

5. Slide the printer back into its case.

6. Turn the latch clockwise to secure the printer to the case.

7. Connect the printer cable to the connector on the rear of the printer. See Cabling the Printer on page B-9.

8. Run the self test described on page B-10 to ensure the paper is installed correctly.

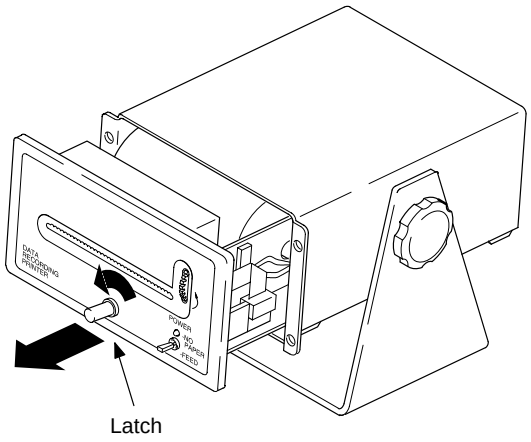


Figure B-6 Removing the Printer from its Case

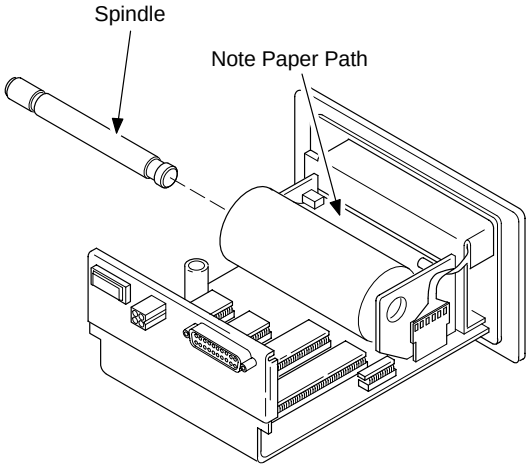


Figure B-7 Install Paper

Caution!

Once the paper enters the feed mechanism, do not pull it back in the direction of the paper roll. Always feed the paper with the thumbwheel.

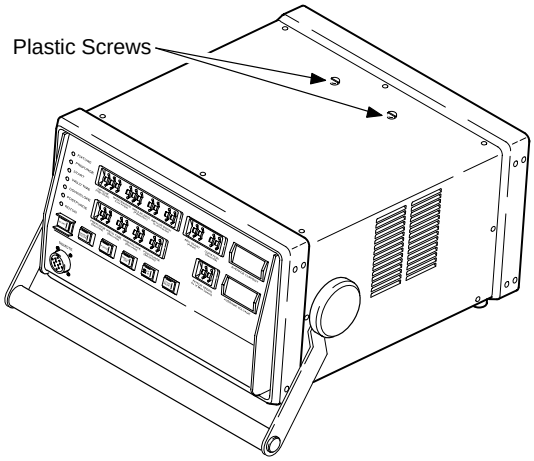


Figure B-8 Remove Plastic Screws

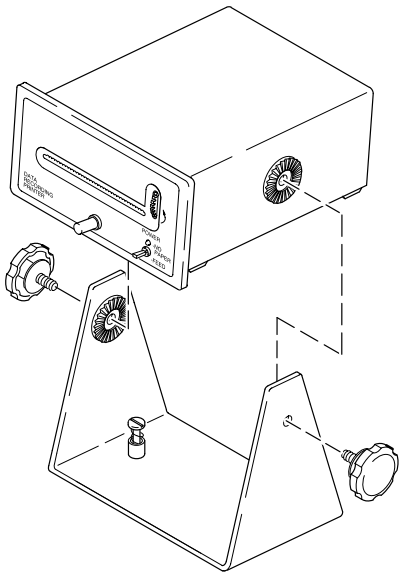


Figure B-9 Separating the Printer from the Mounting Bracket

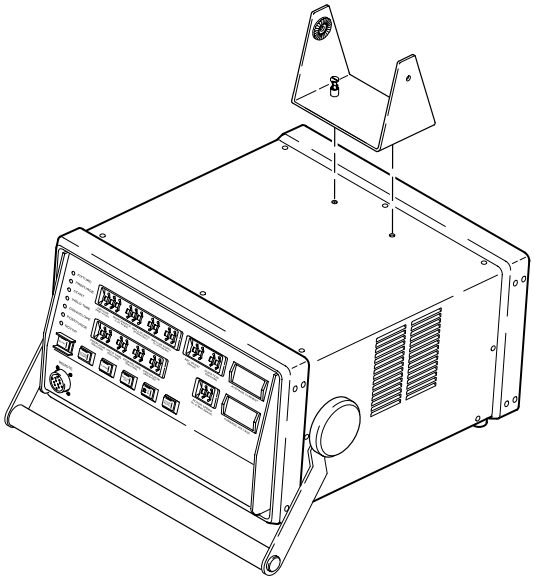


Figure B-10 Mount the Bracket to the Power Supply

Mounting the Printer to the Power Supply

The SWS printer attaches to the top surface of the power supply using a mounting bracket. To mount the printer, do the following:

1. Remove the two 1/4-20 pan head plastic screws from the top panel of the power supply. See Figure B-8.
2. Remove the mounting bracket from the printer by removing the two black knobs. The bracket must be pulled apart somewhat to free the printer, due to the serrated mating surfaces. See Figure B-9.
3. Attach the mounting bracket to the power supply by tightening the two captive thumbscrews in the base of the bracket. See Figure B-10.
4. Install the printer in the mounting bracket and rotate the unit to an appropriate viewing angle. Insert and tighten the two black knobs to secure the printer.

Cabling the Printer

Cable the printer by performing the following steps:

1. Turn the SWS power supply off. Turn the printer power switch off, which is the down position.

2. Plug the interface cable into the 25-pin connector on the back of the printer. The connectors are polarized, so only one end of the cable will match the printer connector. Connect the other end of the cable to the printer connector on the rear of the power supply. See Figure B-11.

3. Turn on the power supply. Do not apply power to the printer at this time.

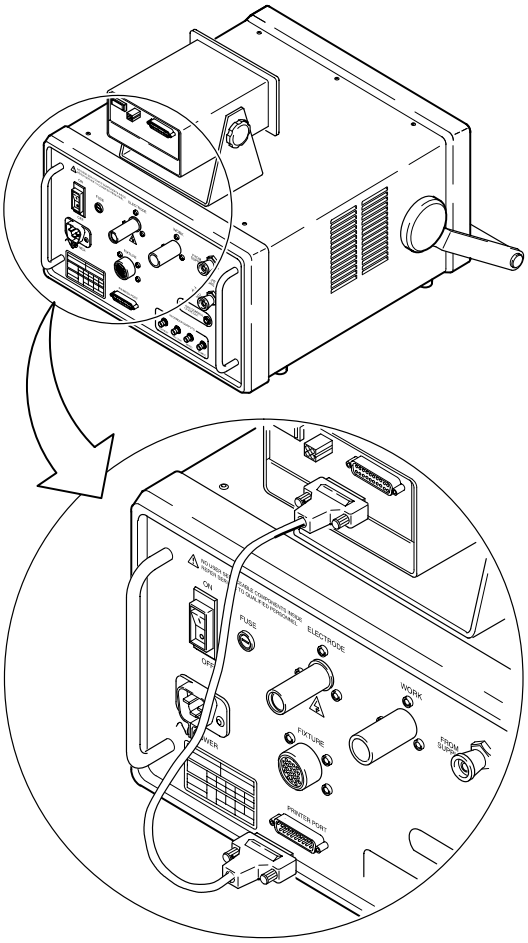


Figure B-11 Connecting the Printer

Operating the Printer

The controls used to operate the CWS-DRP have been kept to a minimum. See Figure B-12. The front panel components and their functions are listed in Table B-1.

Table B-1 Printer Front Panel Controls

Control	Function
THUMBWHEEL	Used to manually advance the paper. The thumbwheel can be advanced in one direction only, indicated by the arrow.
LED	Indicates the power is on when green; indicates paper is out when flashing red, yellow, green.
SWITCH	Down position power off Middle position power on Top position paper advance (spring loaded, momentary)
LATCH	Locks the printer inside the case.

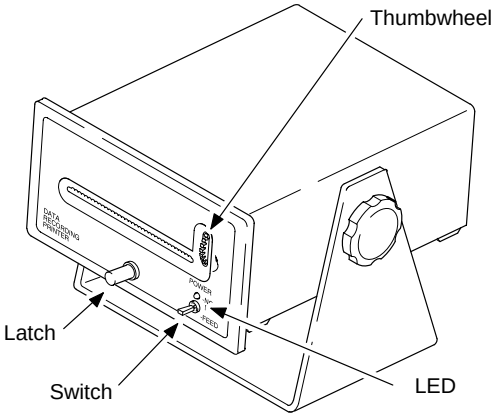


Figure B-12 Printer Front Panel Controls

Performing the Self Test

The printer has a convenient self-test feature. This feature is used to quickly determine if the printer is operating correctly. To activate the self-test feature:

1. Locate the power switch on the front panel. See Figure B-12.
2. Move the power switch from off to the paper advance position and hold it there.

   The paper advance position is the point when the switch is pressed upward to the limit of its travel.
3. Release the power switch once the self-test routine begins.

   The printout is a recurring pattern of symbols, numbers, and letters.
4. Turn off the power switch after several lines of the test pattern have been printed.

For the highest quality output and maximum thermal head life, it is recommended that a premium quality thermal paper be used. (Swagelok part number CWS-DRP-PAPER)

Note: *See page 3-17 for descriptions of the program mode items referenced in this section.*

Using the Printer

Activate the printer from the power supply by one of two methods:

- Press **PRINT** on the power supply front panel.
- Establish an automatic print cycle by setting the automatic print counter (program mode item 21).

The printer will always print the last valid weld data record. If no valid data exists, the average current display will show three dashes (− − −).

Weld Data Record Examples

The example printouts in this section show the SWS weld data record format.

Note the WELD# on each data record. This number is the resettable weld counter value (program mode item 20).

Figure B-13, labeled WELD# 000026, is an example record of an acceptable weld cycle. The power supply controller determines acceptability depending on comparisons of feedback readings of voltage, current, and rotor speed against expected values.

```
 SWAGELOK WELDING SYSTEM DATA RECORD
MODEL D100-1B VER  4.0
SERIAL# 00000001
DATE 02/07/98 TIME 07:46 WELD# 000026
── ── ── ── ── ── INPUT ── ── ── ── ── ──
             IMP    IMP     ARC
IMP   MNT   RATE  WIDTH   START  DUR
50.0  50.0  10    20      10     0.1

 PRE  WELD  DWN  POST          AVG
PURGE TIME  SLP  PURGE SPEED CURRENT
 5    15     5    3    10    50.0
── ── ── ── ── ─ OUTPUT ─ ── ── ── ── ──
              AVG       AVG     TRAVEL
WELD TIME   CURRENT   VOLTAGE   SPEED
            50.2       9.9       10.0
              AVG      AVG      TRAVEL
DOWNSLOPE   CURRENT   VOLTAGE   SPEED
             30.9       6.2      10.0
── ── - PERFORMANCE CONFIRMATION · ── ──
WELD COMPLETE
PERFORMANCE ACCEPTABLE
WELD ID# ── ── ── ── ── ── ── ── ── ── ──
JOB IDENT── ── ── ── ── ── ── ── ── ── ──
OPERATOR IDENT ── ── ── ── ── ── ── ── ──
```

Figure B-13 Weld No. 26

Figure B-14, labeled WELD# 000027, shows an unacceptable weld cycle, caused by a stalled rotor. Note the zero values for the downslope cycle, indicating that the rotor stalled during weld time.

```
 SWAGELOK WELDING SYSTEM DATA RECORD
MODEL D100-1B VER  4.0
SERIAL# 00000001
DATE 02/07/98 TIME 07:46 WELD# 000027
── ── ── ── ── ── INPUT ── ── ── ── ── ──
             IMP    IMP     ARC
IMP   MNT   RATE  WIDTH   START  DUR
50.0  50.0   10    20      10     0.1

 PRE  WELD  DWN  POST          AVG
PURGE TIME  SLP  PURGE SPEED CURRENT
 5    15     5    3    10    50.0
── ── ── ── ── ─ OUTPUT ─ ── ── ── ── ──
              AVG       AVG     TRAVEL
WELD TIME   CURRENT   VOLTAGE   SPEED
            50.2       9.8       10.0
              AVG      AVG      TRAVEL
DOWNSLOPE   CURRENT   VOLTAGE   SPEED
             0.0        0.0       0.0
── ── - PERFORMANCE CONFIRMATION · ── ──
WELD NOT COMPLETE
WELD HEAD ROTOR STALLED
PERFORMANCE NOT ACCEPTABLE
WELD ID# ── ── ── ── ── ── ── ── ── ── ──
JOB IDENT── ── ── ── ── ── ── ── ── ── ──
OPERATOR IDENT ── ── ── ── ── ── ── ── ──
```

Figure B-14 Weld No. 27

```
 SWAGELOK WELDING SYSTEM DATA RECORD
MODEL D100-1B VER  4.0
SERIAL# 00000001
DATE 02/07/98 TIME 07:46 WELD# 000028
── ── ── ── ── ── INPUT ── ── ── ── ── ──
             IMP   IMP     ARC
 IMP   MNT   RATE  WIDTH  START  DUR
 50.0  50.0   10    20    10     0.1

  PRE  WELD  DWN  POST         AVG
 PURGE TIME  SLP  PURGE SPEED CURRENT
  5    15     5    3    10    50.0
── ── ── ── ── ─ OUTPUT ─ ── ── ── ── ──
              AVG      AVG    TRAVEL
 WELD TIME  CURRENT  VOLTAGE  SPEED
            50.1      9.8      10.1
              AVG     AVG     TRAVEL
 DOWNSLOPE  CURRENT  VOLTAGE  SPEED
             31.2      6.2     10.1
── ── - PERFORMANCE CONFIRMATION · ── ──
WELD NOT COMPLETE
DOWNSLOPE PUSHBUTTON PRESSED
PERFORMANCE NOT ACCEPTABLE
WELD ID# ── ── ── ── ── ── ── ── ── ── ──
JOB IDENT── ── ── ── ── ── ── ── ── ── ──
OPERATOR IDENT ── ── ── ── ── ── ── ── ──
```

Figure B-15 Weld No. 28

Figure B-15, labeled WELD# 000028, shows that the weld cycle was interrupted by pressing **DOWNSLOPE**.

```
 SWAGELOK WELDING SYSTEM DATA RECORD
MODEL D100-1B VER  4.0
SERIAL# 00000001
DATE 02/07/98 TIME 07:46 WELD# 000029
── ── ── ── ── ── INPUT ── ── ── ── ── ──
             IMP   IMP     ARC
 IMP   MNT   RATE  WIDTH  START  DUR
 50.0  50.0   10    20    10     0.1

  PRE  WELD  DWN  POST         AVG
 PURGE TIME  SLP  PURGE SPEED CURRENT
  5    15     5    3    10    50.0
── ── ── ── ── ─ OUTPUT ─ ── ── ── ── ──
              AVG      AVG    TRAVEL
 WELD TIME  CURRENT  VOLTAGE  SPEED
            50.2      9.8      10.1
              AVG     AVG     TRAVEL
 DOWNSLOPE  CURRENT  VOLTAGE  SPEED
             0.0       0.0      0.0
── ── - PERFORMANCE CONFIRMATION · ── ──
WELD NOT COMPLETE
ARC FAILURE
PERFORMANCE NOT ACCEPTABLE
WELD ID# ── ── ── ── ── ── ── ── ── ── ──
JOB IDENT── ── ── ── ── ── ── ── ── ── ──
OPERATOR IDENT ── ── ── ── ── ── ── ── ──
```

Figure B-16 Weld No. 29

Figure B-16, labeled WELD# 000029, shows that the arc failed sometime during the weld cycle. Again note that the weld time output readings seem normal, but the downslope readings are zero. This indicates that the arc failed during weld time.

Figure B-17, labeled WELD# 000030, shows a weld cycle that was not acceptable. Although the power supply did complete the cycle, the rotor speed output did not match the programmed value. The weld may in fact be acceptable in this case, but the condition is flagged nonetheless.

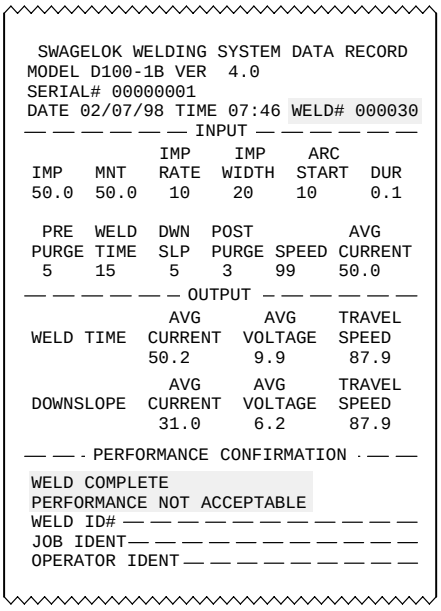


Figure B-17 Weld No. 30

Figure B-18, labeled WELD# 000301, shows another weld cycle that was not completed. The error was caused by pressing the **STOP/RESET** pushbutton during the weld cycle.

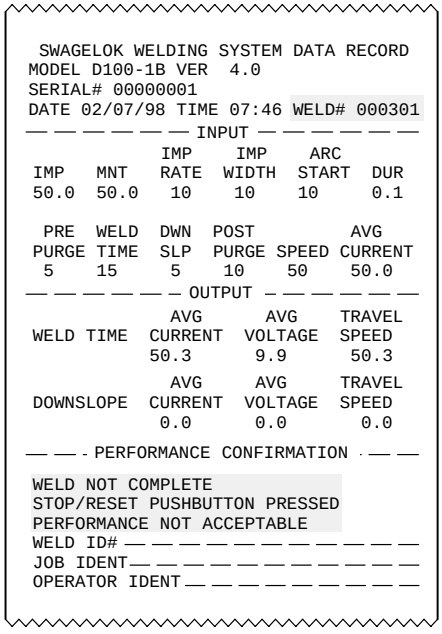


Figure B-18 Weld No. 301

User Parameter Printout

```
SWAGELOK WELDING SYSTEM USER PARAMETERS
MODEL D100-1B VER  4.0
SERIAL# 00000001
DATE 02/07/98 TIME 07:46


20: resettable weld counter:  29
21: Automatic print count:  5
22: Monitor Polarity: ACTIVE HIGH (1)
23: Arc Start Power (0)
35: Date format: DD?MM?YY (1)
60: Non-resettable weld count:  1217
61: Non-resettable arc starts:  1239
Configuration dipswitch: 00
```

Figure B-19 User Parameter Printout

The power supply can print a record showing the state of various programmable counters, the date format, and other system information. See Figure B-19.

The printout is initiated by accessing item 99 in the program mode of operation. See the description in Section 3, *Operation*, for user instructions for the program mode.

Maintenance

The SWS printer is designed to require a minimum of maintenance and service. Contact your Swagelok representative for any electrical or mechanical repairs that must be performed.

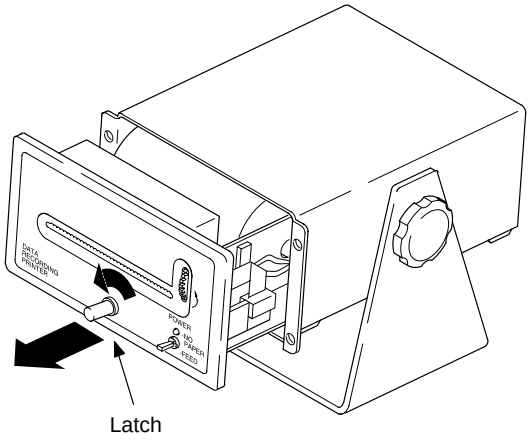


Figure B-20 Removing the Printer from its Case

Clearing Paper Jams

In the event of a paper jam condition do not force paper into the unit or try to pry the paper out of the unit. This may damage the thermal print mechanism.

1. Turn off the printer power switch and disconnect the printer cable from the rear of the printer.

2. Turn the latch counter-clockwise to release the printer body from the case. Remove the printer body from the case by pulling it forward. See Figure B-20.

3. Cut the paper off at the roll. Carefully remove the paper in the printer mechanism by advancing the thumbwheel or using tweezers or small needle nose pliers. Remove the paper through the front of the printer. See Figure B-21.

4. Reload the paper after the jam has been cleared.

5. Slide the printer back into the printer case and tighten the latch.

6. Connect the printer cable to the connector on the rear of the printer.

7. Run a self-test to verify that the paper is installed correctly.

Caution!

Do not pull the paper backwards toward the paper roll. This can damage the print head mechanism.

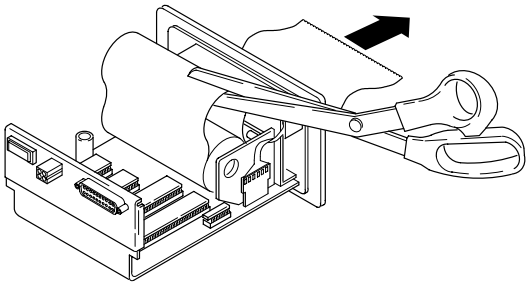


Figure B-21 Clearing a Paper Jam

Cleaning

The exterior SWS printer cabinet may be cleaned with a non-abrasive cleaner. Take care to prevent liquids from entering the mechanical assembly.

Using a Standard RS-232 Printer

Caution!

The CWS-DRP printer interface supplies 15 V power on the interface cable. Some serial printers could be damaged by this power supply voltage.

It is possible to interface a standard RS-232 (serial) printer to the power supply. However, specific requirements must be met by the printer to ensure compatibility.

The serial printer must have the following minimum capabilities:

- printing ASCII characters
- have a 40-character column width
- baud 9600
- stop 1
- parity none
- data 8
- buffer > 200 characters (suggest 2000)

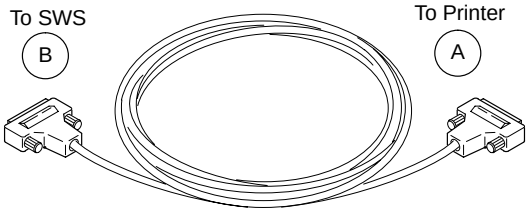


Figure B-22 Modified RS-232 Printer Cable Pinout

See Figure B-22. Use the cable pin designations in the table below to create an interface cable. Note that the table describes the signal wiring on the B side of the cable. The B connector must have male pins to properly mate to the printer connector. The A side of the cable is wired to RS-232 standards.

Table B-2 Interface Cable B Connector Wiring

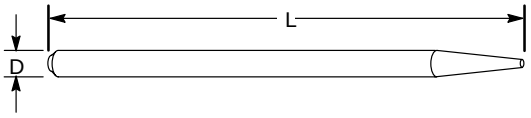
B Side Connector Pin No.	Signal Name from SWS D100
2	Transmit
3	Receive
5	Clear to send (CTS)
7	Signal ground
9	+15 V (dc)**
20	Data Transmit Ready (DTR)
24	Ground

** Power to CWS-DRP. Do not wire to standard printer.

Appendix C
Electrode Selection Tables and Geometry

CWS-4MRH-A, CWS-4MFH-A Micro Weld Heads

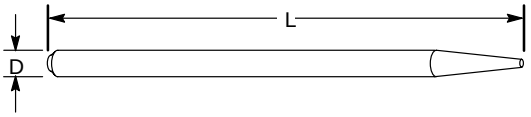
Electrode Part No.	Component OD	Electrode Length (L)	Electrode Diameter (D)
CWS-C.040-.405-P	1/8 in. 1/16 in. 3 mm	0.405 in. (10,29 mm)	0.040 in. (1,02 mm)
CWS-C.040-.325-P	1/4 in. 6 mm	0.325 in. (8,26 mm)	0.040 in. (1,02 mm)



CWS-8MRH Micro Weld Head

Electrode Part No.	Component OD*	Electrode Length (L)	Electrode Diameter (D)
CWS-C.040-.405-P	1/4 in. 6,8 mm	0.405 in. (10,29 mm)	0.040 in. (1,02 mm)
CWS-C.040-.325-P	3/8 in. 10 mm	0.325 in. (8,26 mm)	0.040 in. (1,02 mm)
CWS-C.040-.281-P	1/2 in. 12 mm	0.281 in. (7,14 mm)	0.040 in. (1,02 mm)

*1/2 in., 12 mm ATW fittings are outside the usable range



CWS-5H-B Weld Head

Electrode Part No.	Component OD	Electrode Length (L)	Electrode Diameter (D)
CWS-C.040-.705-P	1/8 in. 3/16 in. 3 mm	0.705 in. (17,90 mm)	0.040 in. (1,02 mm)
CWS-C.040-.605-P	1/4 in. 5/16 in. 6 mm 8 mm	0.605 in. (15,37 mm)	0.040 in. (1,02 mm)
CWS-C.040-.555-P	3/8 in. 1/2 in. 10 mm 12 mm	0.555 in. (14,10 mm)	0.040 in. (1,02 mm)
CWS-C.040-.450-P	5/8 in. 15 mm	0.450 in. (11,43 mm)	0.040 in. (1,02 mm)
CWS-C.040-.405-P	16 mm	0.405 in. (10,29 mm)	0.040 in. (1,02 mm)

CWS-10H-A Weld Head

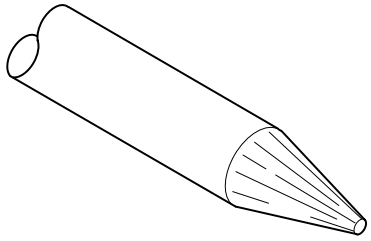
CWS-C.062-1.105-P	1/4 in. 3/8 in. 1/2 in. 6 mm 8 mm 10 mm 12 mm 14 mm 15 mm	1.105 in. (28,07 mm)	0.062 in. (1,57 mm)
CWS-C.062-.855-P	3/4 in. 7/8 in. 18 mm 22 mm 1 in. 23 mm 25 mm	0.855 in. (21,72 mm)	0.062 in. (1,57 mm)

CWS-20H-A/B Weld Head

Electrode Part No.	Component OD	Pipe	Electrode Length (L)	Electrode Diameter (D)
CWS-C.062-1.630-P	1/2 in. 3/4 in. 12 mm 18 mm 22 mm	1/4 1/2 3/8	1.630 in. (41,40 mm)	0.062 in. (1,57 mm)
CWS-C.062-1.380-P	1 in. 1 1/4 in. 23 mm 25 mm 28 mm 35 mm	3/4 1	1.380 in. (35,05 mm)	0.062 in. (1,57 mm)
CWS-C.062-1.105-P	1 1/2 in. 35 mm		1.105 in. (28,07 mm)	0.062 in. (1,57 mm)
CWS-C.062-.855-P	1 3/4 in. 2 in. 35 mm 40 mm 52 mm	1 1/4 1 1/2	0.855 in. (21,72 mm)	0.062 in. (1,57 mm)

Electrode Geometry

This illustration shows the electrode shape Swagelok suggests. Properly ground electrodes provide consistent, repeatable welds. Pre-ground electrodes are available from your Swagelok representative. See your parts list for ordering information.



The electrode part numbers are assigned as follows:

CWS – X.### – #.### – P

- Package Designator
- Electrode Length
- Electrode Diameter
- Material Designator
  - C = Ceriated
  - T = Thoriated

The ceriated electrode material type is a mixture of 98 % tungsten and 2 % cerium and is commonly referred to as “2 % ceriated.” This electrode type has demonstrated improved arc starting performance over the 2 % thoriated type, particularly when using purified shielding gas.

Appendix D
Weld Head Information

Weld Head Series	Shield Gas Flow Rates std ft3/hr (std L/min)	Prepurge and Postpurge minimum time in seconds	Start Power	Maximum Recommended Average Amps
4	8 to 10 (4,7 to 4,7)	Continuous	Low	30 A
8	15 to 20 (7,1 to 9,4)	Continuous	Low	38 A NOTE 4
5	10 to 15 (4,7 to 7,1)	20 NOTE 2	Normal NOTE 3	50 A
10	10 to 20 NOTE 1 (4,7 to 9,4)	20 NOTE 2	Normal NOTE 3	100 A
20-A	10 to 20 NOTE 1 (4,7 to 9,4)	30 NOTE 2	Normal	100 A
20−B	20 to 40 NOTE 1 (9,4 to 18,8)	30 NOTE 2	Normal	100 A

NOTE

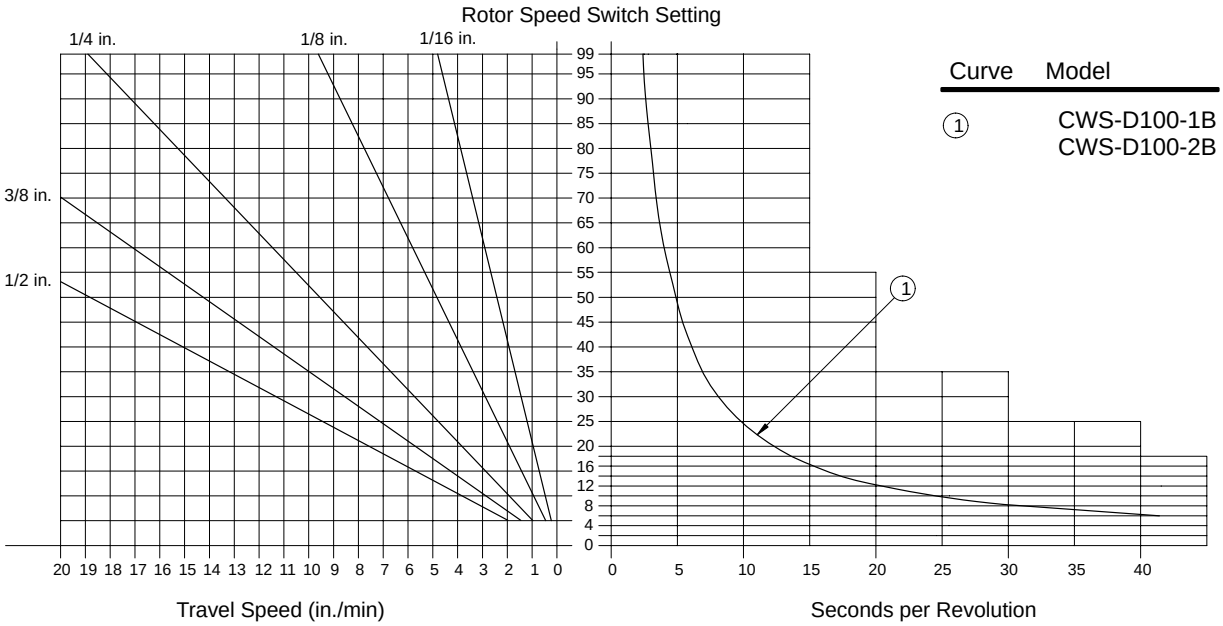
1 Set flow to higher rates when welding at high current rates.

2 Flow should be continuous for cooling when welding at high current rates.

3 When welding wall thickness of 0.020 in. (0,5 mm) or less, use low start power and an arc gap of 0.035 in. (0,89 mm) or less.

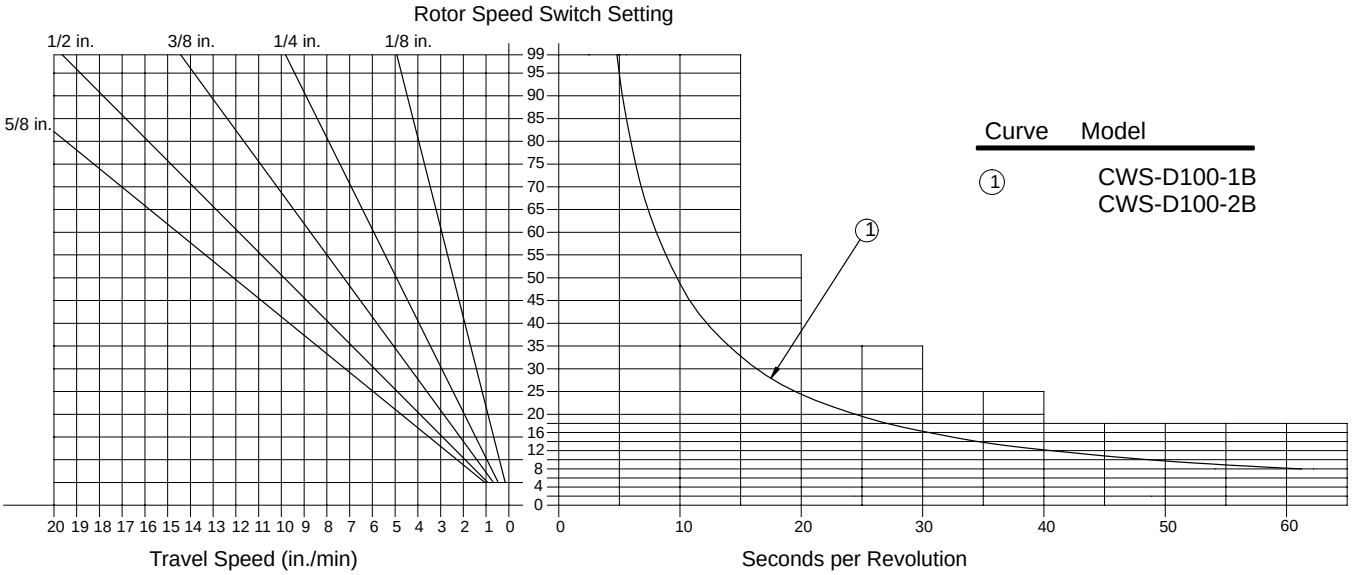
4 When welding 1/2 in. or 12 mm OD with a Series 8 weld head, use the single pass (one revolution) weld procedure only.

Travel Speed (in./min)	vs.	Rotor Speed Switch Setting	vs.	Seconds per Revolution



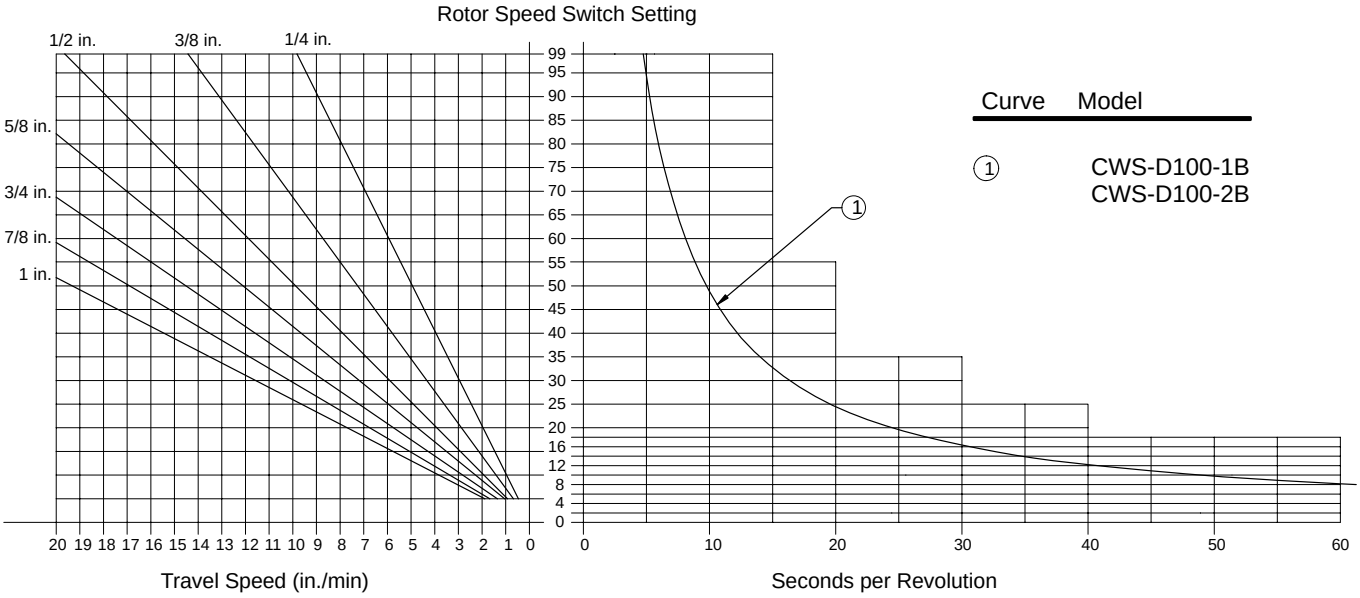
MICRO WELD HEAD − TUBE WELDING

Travel Speed (in./min)	vs.	Rotor Speed Switch Setting	vs.	Seconds per Revolution



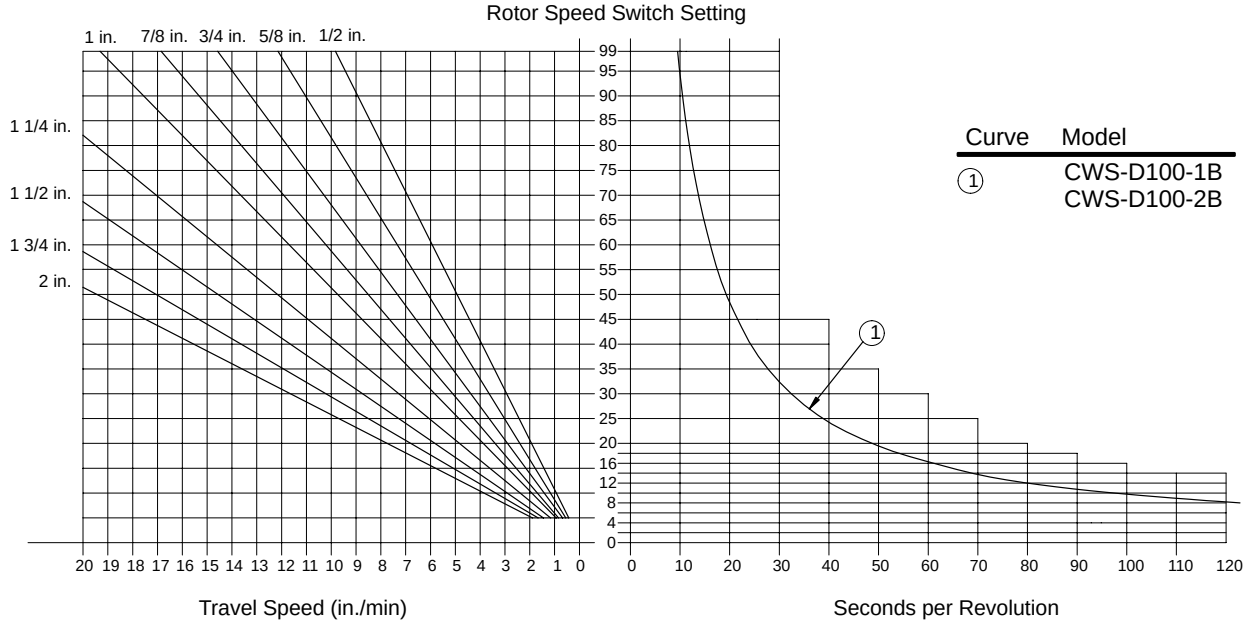
SERIES 5 WELD HEAD − TUBE WELDING

Travel Speed (in./min)	vs.	Rotor Speed Switch Setting	vs.	Seconds per Revolution



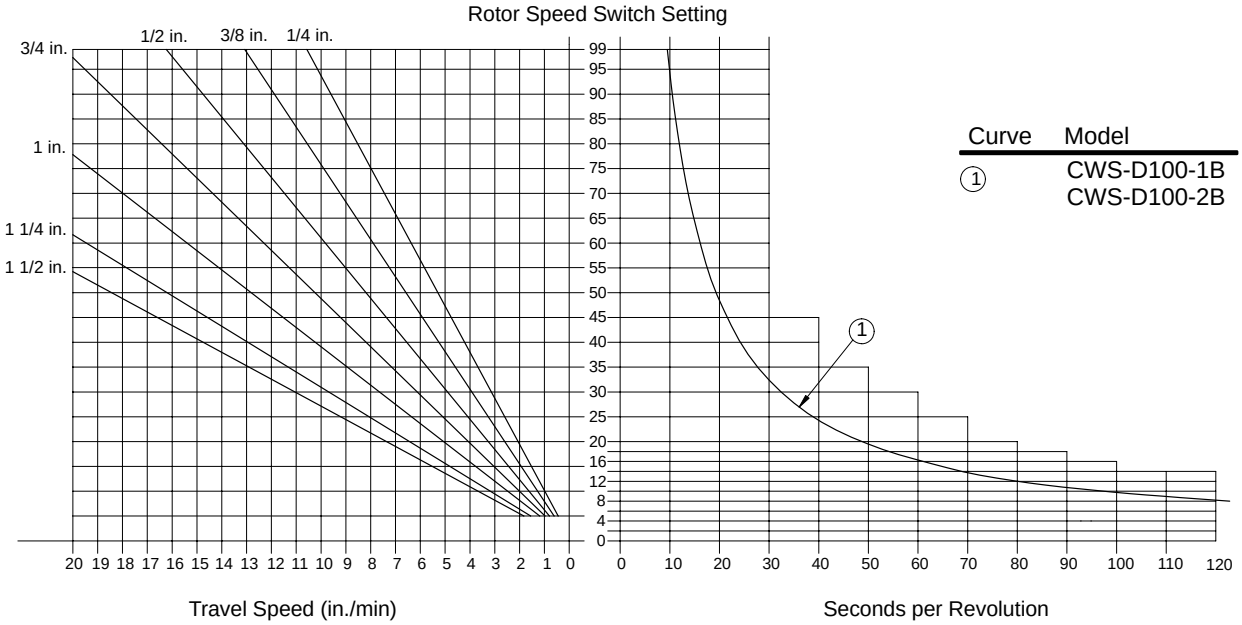
SERIES 10 WELD HEAD − TUBE WELDING

Travel Speed (in./min)	vs.	Rotor Speed Switch Setting	vs.	Seconds per Revolution



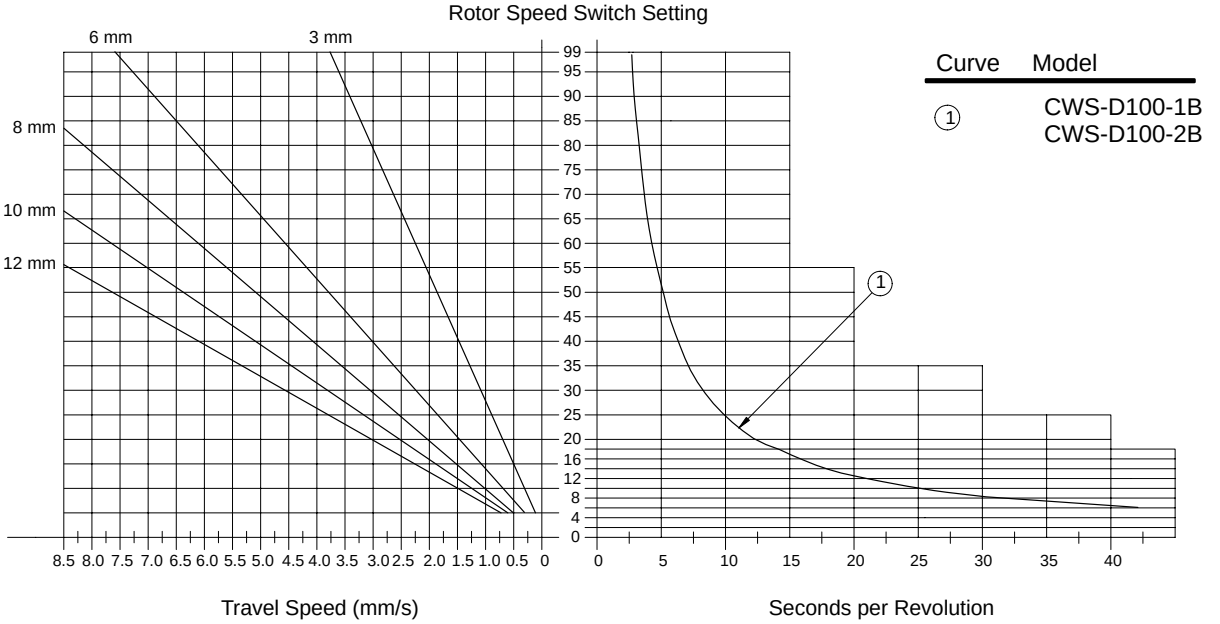
SERIES 20 WELD HEAD − TUBE WELDING

Travel Speed (in./min)	vs.	Rotor Speed Switch Setting	vs.	Seconds per Revolution



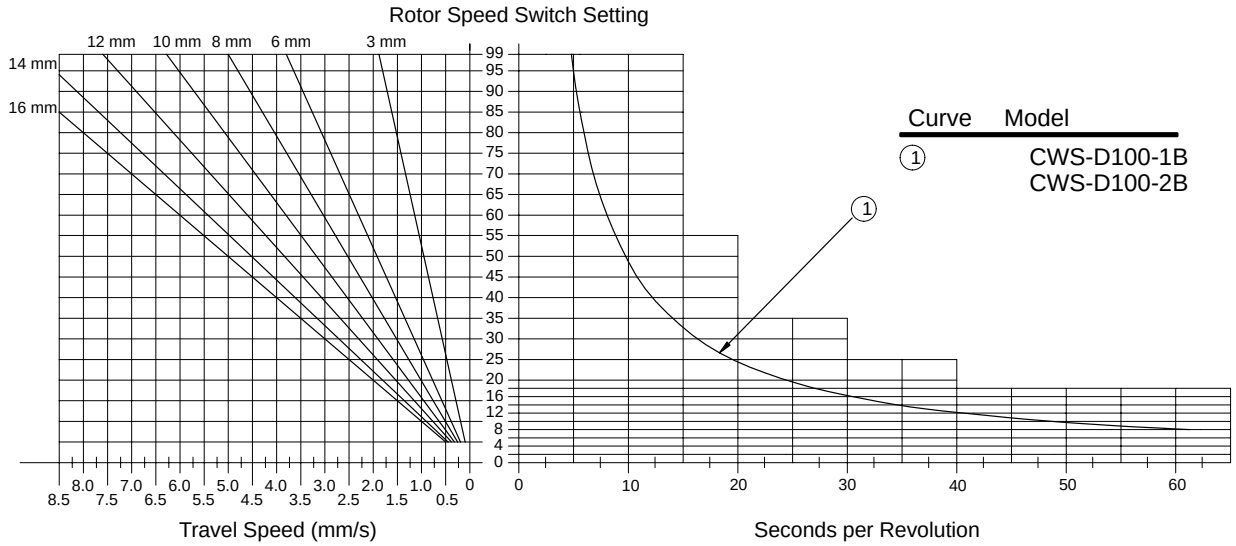
SERIES 20 WELD HEAD − PIPE WELDING

Travel Speed (mm/s)	vs.	Rotor Speed Switch Setting	vs.	Seconds per Revolution



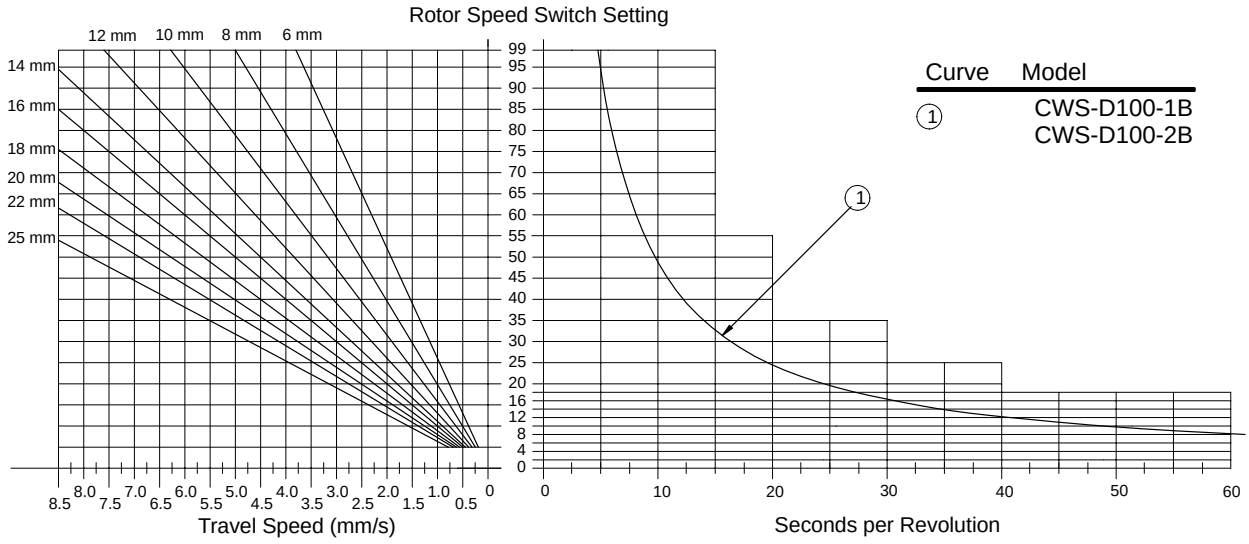
MICRO WELD HEAD − TUBE WELDING

Travel Speed (mm/s)	vs.	Rotor Speed Switch Setting	vs.	Seconds per Revolution



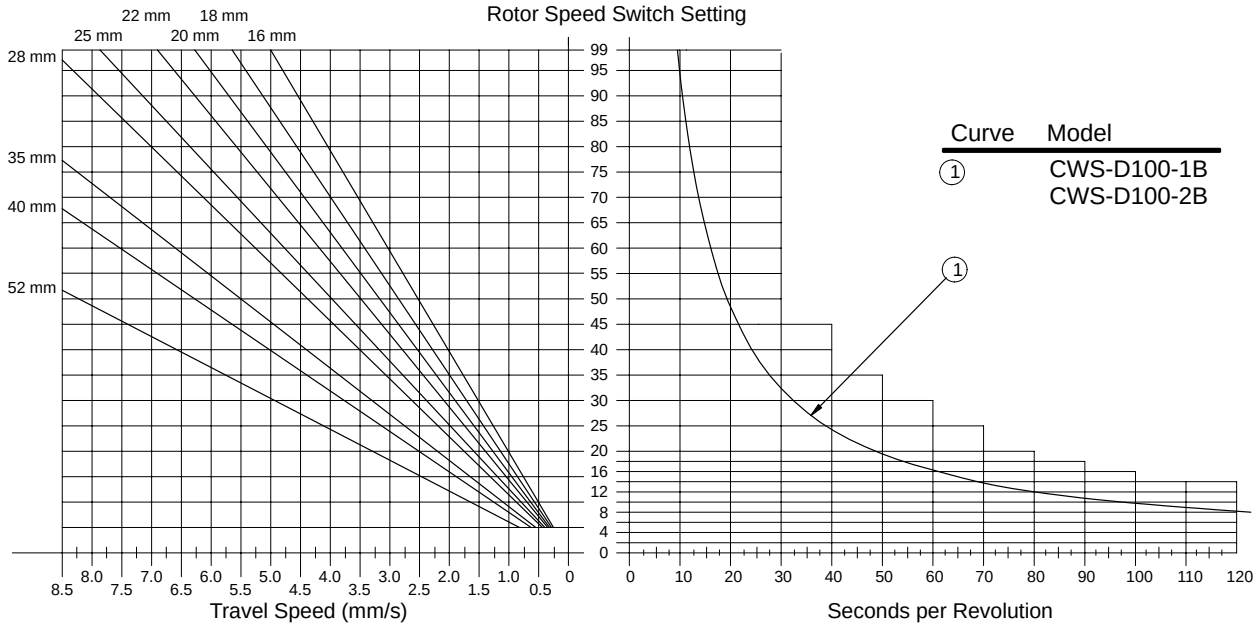
SERIES 5 WELD HEAD − TUBE WELDING

Travel Speed (mm/s)	vs.	Rotor Speed Switch Setting	vs.	Seconds per Revolution



SERIES 10 WELD HEAD − TUBE WELDING

Travel Speed (mm/s)	vs.	Rotor Speed Switch Setting	vs.	Seconds per Revolution



SERIES 20 WELD HEAD − TUBE WELDING

Appendix E
Arc Gap Gage Setting Tables

Wall Thickness and Arc Gap

Material Thickness (mm)		Arc Gap	
in.	mm	in.	mm
0.010 to 0.020	0,25 to 0,51	0.020	0,51
0.021 to 0.030	0,52 to 0,76	0.025	0,64
0.031 to 0.045	0,77 to 1,14	0.030	0,76
0.046 to 0.055	1,15 to 1,40	0.035	0,89
0.056 to 0.064	1,41 to 1,63	0.040	1,02
0.065 to 0.082	1,64 to 2,28	0.045	1,14
0.083 to 0.154	2,29 to 4,00	0.050	1,39

Caution!

Check recommended weld arc gap ranges for each weld head. Refer to the following tables.

Note: *When welding ATW fittings and weld rings, be sure to add the cuff thickness to the wall thickness (see Table 5-3 on page 5-4).*

Weld Head Arc Gap Gage Setting Tables

CWS-4MRH-A, CWS-4MFH-A Arc Gap Gage Dia. 0.620 in.

Nominal OD (in.)	Actual OD (in.)	Setting for 0.020 in. Arc Gap (in.)	Setting for 0.025 in. Arc Gap (in.)	Setting for 0.030 in. Arc Gap (in.)	Setting for 0,51 mm Arc Gap (mm)	Setting for 0,64 mm Arc Gap (mm)	Setting for 0,76 mm Arc Gap (mm)
	0.057	0.359	0.364	0.369	9,13	9,26	9,38
	0.059	0.360	0.365	0.370	9,15	9,28	9,40
1/16	0.062	0.361	0.367	0.372	9,19	9,32	9,44
	0.065	0.363	0.368	0.373	9,25	9,36	9,48
	0.067	0.364	0.369	0.374	9,26	9,39	9,51
	0.120	0.391	0.396	0.401	9,93	10,06	10,18
	0.122	0.392	0.397	0.402	9,95	10,08	10,20
1/8	0.125	0.393	0.398	0.403	9,99	10,12	10,24
	0.128	0.395	0.400	0.405	10,03	10,16	10,28
	0.130	0396	0.401	0.406	10,06	10,19	10,31
	0.245	0.453	0.458	0.463	11,52	11,65	11,77
	0.247	0.454	0.459	0.464	11,54	11,67	11,79
1/4	0.250	0.456	0.461	0.466	11,58	11,71	11,83
	0.253	0.457	0.462	0.467	11,62	11,75	11,87
	0.255	0.458	0.463	0.468	11,64	11,77	11,89

CWS-4MRH-A, CWS-4MFH-A Arc Gap Gage Dia. 15,75 mm

Nominal OD (mm)	Actual OD (mm)	Setting for 0,51 mm Arc Gap (mm)	Setting for 0,64 mm Arc Gap (mm)	Setting for 0,76 mm Arc Gap (mm)
	2,87	9,84	9,97	10,09
	2,92	9,87	10,00	10,12
3	3,00	9,91	10,04	10,16
	3,05	9,93	10,06	10,18
	3,12	9,97	10,10	10,22
	5,87	11,34	11,47	11,59
	5,94	11,38	11,51	11,63
6	6,00	11,41	11,54	11,66
	6,05	11,43	11,56	11,68
	6,12	11,47	11,60	11,72

CWS-8MRH
Arc Gap Gage Dia. 0.813 in.

Nominal OD (in.)	Actual OD (in.)	Setting for 0.020 in. Arc Gap (in.)	Setting for 0.025 in. Arc Gap (in.)	Setting for 0.030 in. Arc Gap (in.)	Setting for 0.035 in. Arc Gap (in.)	Setting for 0,51 mm Arc Gap (mm)	Setting for 0,64 mm Arc Gap (mm)	Setting for 0,77 mm Arc Gap (mm)	Setting for 0,89 mm Arc Gap (mm)
	0.245	0.549	0.554	0.559	0.564	13,95	14,08	14,21	14,33
	0.247	0.550	0.555	0.560	0.565	13,97	14,10	14,23	14,35
1/4	0.250	0.552	0.557	0.562	0.567	14,02	14,15	14,28	14,40
	0.253	0.553	0.558	0.563	0.568	14,05	14,18	14,31	14,43
	0.255	0.554	0.559	0.564	0.569	14,07	14,20	14,33	14,45
	0.370	0.612	0.617	0.622	0.627	15,55	15,68	15,81	15,93
	0.372	0.613	0.618	0.623	0.628	15,57	15,70	15,83	15,95
3/8	0.375	0.615	0.620	0.625	0.629	15,60	15,73	15,86	15,98
	0.378	0.616	0.621	0.626	0.631	15,65	15,78	15,91	16,03
	0.380	0.617	0.622	0.627	0.632	15,67	15,80	15,93	16,05
	0.495	0.674	0.679	0.684	0.689	17,12	17,25	17,38	17,50
	0.497	0.675	0.680	0.685	0.690	17,15	17,28	17,41	17,53
1/2	0.500	0.677	0.682	0.687	0.692	17,20	17,33	17,46	17,58
	0.503	0.678	0.683	0.688	0.693	17,22	17,35	17,48	17,60
	0.505	0.679	0.684	0.689	0.694	17,25	17,38	17,51	17,63

CWS-8MRH
Arc Gap Gage Dia. 20,65 mm

Nominal OD (mm)	Actual OD (mm)	Setting for 0,51 mm Arc Gap	Setting for 0,64 mm Arc Gap	Setting for 0,76 mm Arc Gap	Setting for 0,89 mm Arc Gap
6	5,87	13,77	13,90	14,02	14,15
	5,92	13,79	13,92	14,04	14,17
	6,00	13,84	13,97	14,09	14,22
	6,07	13,87	14,00	14,12	14,25
	6,12	13,89	14,02	14,14	14,27
8	7,87	14,76	14,89	15,01	15,14
	7,92	14,78	14,91	15,03	15,16
	8,00	14,83	14,96	15,08	15,21
	8,08	14,86	14,99	15,11	15,24
	8,13	14,89	15,02	15,14	15,27
10	9,88	17,12	17,25	17,37	17,50
	9,93	17,15	17,28	17,40	17,53
	10,00	17,20	17,33	17,45	17,58
	10,08	17,22	17,35	17,47	17,60
	10,14	17,25	17,38	17,50	17,63
12	11,86	16,77	16,90	17,02	17,15
	11,91	16,79	16,92	17,04	17,17
	12,00	16,84	16,97	17,09	17,22
	12,07	16,87	17,00	17,12	17,25
	12,12	16,89	17,02	17,14	17,27

CWS-5H-B
Arc Gap Gage Dia. 1.244 in.

Nominal OD (in.)	Actual OD (in.)	Setting for 0.025 in. Arc Gap (in.)	Setting for 0.030 in. Arc Gap (in.)	Setting for 0.035 in. Arc Gap (in.)	Setting for 0.040 in. Arc Gap (in.)	Setting for 0,51 mm Arc Gap (mm)	Setting for 0,64 mm Arc Gap (mm)	Setting for 0,89 mm Arc Gap (mm)	Setting for 1,02 mm Arc Gap (mm)
	0.120	0.707	0.712	0.717	0.722	17,83	17,96	18,21	18,34
	0.122	0.708	0.713	0.718	0.723	17,86	17,99	18,24	18,37
1/8	0.125	0.710	0.715	0.720	0.725	17,91	18,04	18,29	18,42
	0.128	0.711	0.716	0.721	0.726	17,93	18,06	18,31	18,44
	0.130	0.712	0.717	0.722	0.727	17,96	18,09	18,34	18,47
	0.245	0.770	0.775	0.780	0.785	19,43	19,56	19,81	19,94
	0.247	0.771	0.776	0.781	0.786	19,44	19,57	19,82	19,95
1/4	0.250	0.772	0.777	0.782	0.787	19,48	19,61	19,86	19,99
	0.253	0.774	0.779	0.784	0.789	19,53	19,66	19,91	20,04
	0.255	0.775	0.780	0.785	0.790	19,56	19,69	19,94	20,07
	0.370	0.832	0.837	0.842	0.847	21,01	21,14	21,39	21,52
	0.372	0.833	0.838	0.843	0.848	21,03	21,16	21,41	21,54
3/8	0.375	0.835	0.840	0.845	0.850	21,08	21,21	21,46	21,59
	0.378	0.836	0.841	0.846	0.851	21,11	21,24	21,49	21,62
	0.380	0.837	0.842	0.847	0.852	21,13	21,26	21,51	21,64
	0.495	0.895	0.900	0.905	0.910	22,59	22,72	22,97	23,10
	0.497	0.896	0.901	0.906	0.911	22,63	22,76	23,01	23,14
1/2	0.500	0.897	0.902	0.907	0.912	22,66	22,79	23,04	23,17
	0.503	0.899	0.904	0.909	0.914	22,71	22,84	23,09	23,22
	0.505	0.900	0.905	0.910	0.915	22,73	22,86	23,11	23,24
	0.620	0.957	0.962	0.967	0.972	24,18	24,31	24,56	24,69
	0.622	0.958	0.963	0.968	0.973	24,21	24,34	24,59	24,72
5/8	0.625	0.960	0.965	0.970	0.975	24,25	24,38	24,63	24,76
	0.628	0.961	0.966	0.971	0.976	24,28	24,41	24,66	24,79
	0.630	0.962	0.967	0.972	0.977	24,31	24,44	24,69	24,82

CWS-5H-B
Arc Gap Gage Dia. 31,60 mm

Nominal OD (mm)	Actual OD (mm)	Setting for 0,50 mm Arc Gap (mm)	Setting for 0,64 mm Arc Gap (mm)	Setting for 0,76 mm Arc Gap (mm)	Setting for 0,89 mm Arc Gap (mm)	Setting for 1,02 mm Arc Gap (mm)
	2,87	17,73	17,87	17,99	18,12	18,25
	2,92	17,76	17,90	18,02	18,15	18,28
3	3,00	17,80	17,94	18,06	18,19	18,32
	3,08	17,84	17,98	18,10	18,23	18,36
	3,12	17,86	18,00	18,12	18,25	18,38
	5,87	19,23	19,37	19,49	19,62	19,75
	5,92	19,27	19,41	19,53	19,66	19,79
6	6,00	19,30	19,44	19,56	19,69	19,82
	6,08	19,34	19,48	19,60	19,73	19,86
	6,12	19,36	19,50	19,62	19,75	19,88
	7,87	20,24	20,38	20,50	20,63	20,76
	7,92	20,27	20,41	20,53	20,66	20,79
8	8,00	20,30	20,44	20,56	20,69	20,82
	8,08	20,34	20,48	20,60	20,73	20,86
	8,13	20,36	20,50	20,62	20,75	20,88
	9,88	21,24	21,38	21,50	21,63	21,76
	9,92	21,27	21,41	21,53	21,66	21,79
10	10,00	21,30	21,44	21,56	21,69	21,82
	10,08	21,34	21,48	21,60	21,73	21,86
	10,14	21,37	21,51	21,63	21,76	21,89
	11,87	22,24	22,38	22,50	22,63	22,76
	11,92	22,26	22,40	22,52	22,65	22,78
12	12,00	22,30	22,44	22,56	22,69	22,82
	12,07	22,33	22,47	22,59	22,72	22,85
	12,13	22,36	22,50	22,62	22,75	22,88

CWS-10H-A
Arc Gap Gage Dia. 1.994 in.

Nominal OD (in.)	Actual OD	Setting for 0.025 in. Arc Gap (in.)	Setting for 0.030 in. Arc Gap (in.)	Setting for 0.035 in. Arc Gap (in.)	Setting for 0.040in. Arc Gap (in.)	Setting for 0.045 in. Arc Gap (in.)	Setting for 0,50 mm Arc Gap (mm)	Setting for 0,64 mm Arc Gap (mm)	Setting for 0,76 mm Arc Gap (mm)	Setting for 1,02 mm Arc Gap (mm)	Setting for 1,14 mm Arc Gap (mm)
	0.245	1.144	1.149	1.154	1.159	1.164	28,93	29,07	29,19	29,45	29,57
	0.247	1.145	1.150	1.155	1.160	1.165	28,95	29,09	29,21	29,47	29,59
1/4	0.250	1.147	1.152	1.157	1.162	1.167	29,00	29,14	29,26	29,52	29,64
	0.253	1.148	1.153	1.158	1.163	1.168	29,04	29,18	29,30	29,56	29,68
	0.255	1.149	1.154	1.159	1.164	1.169	29,07	29,21	29,33	29,59	29,71
	0.370	1.207	1.212	1.217	1.222	1.227	30,53	30,67	30,79	31,05	31,17
	0.372	1.208	1.213	1.218	1.223	1.228	30,55	30,69	30,81	31,07	31,19
3/8	0.375	1.209	1.214	1.219	1.224	1.229	30,58	30,72	30,84	31,10	31,22
	0.378	1.211	1.216	1.221	1.226	1.231	30,63	30,77	30,89	31,15	31,27
	0.380	1.212	1.217	1.222	1.227	1.232	30,65	30,79	30,91	31,17	31,29
	0.495	1.269	1.274	1.279	1.284	1.289	32,10	32,24	32,36	32,62	32,74
	0.497	1.270	1.275	1.280	1.285	1.290	32,13	32,27	32,39	32,65	32,77
1/2	0.500	1.272	1.277	1.282	1.287	1.292	32,18	32,32	32,44	32,70	32,82
	0.503	1.273	1.278	1.283	1.288	1.293	32,20	32,34	32,46	32,72	32,84
	0.505	1.274	1.279	1.284	1.289	1.294	32,23	32,37	32,49	32,75	32,87
	0.620	1.332	1.337	1.342	1.347	1.352	33,70	33,84	33,96	34,22	34,34
	0.622	1.333	1.338	1.343	1.348	1.353	33,73	33,87	33,99	34,25	34,37
5/8	0.625	1.335	1.340	1.345	1.350	1.355	33,76	33,90	34,02	34,28	34,40
	0.628	1.336	1.341	1.346	1.351	1.356	33,80	33,94	34,06	34,32	34,44
	0.630	1.337	1.342	1.347	1.352	1.357	33,83	33,97	34,09	34,35	34,47
	0.745	1.394	1.399	1.404	1.409	1.414	35,28	35,42	35,54	35,80	35,92
	0.747	1.395	1.400	1.405	1.410	1.415	35,30	35,44	35,56	35,82	35,94
3/4	0.750	1.397	1.402	1.407	1.412	1.417	35,35	35,49	35,61	35,87	35,99
	0.753	1.398	1.403	1.408	1.413	1.418	35,38	35,52	35,64	35,90	36,02
	0.755	1.399	1.404	1.409	1.414	1.419	35,42	35,56	35,68	35,94	36,06
	0.870	1.457	1.462	1.467	1.472	1.477	36,88	37,02	37,14	37,40	37,52
	0.872	1.458	1.463	1.468	1.473	1.478	36,90	37,04	37,16	37,42	37,54
7/8	0.875	1.460	1.465	1.470	1.475	1.480	36,94	37,08	37,20	37,46	37,58
	0.878	1.461	1.466	1.471	1.476	1.481	36,98	37,12	37,24	37,50	37,62
	0.880	1.462	1.467	1.472	1.477	1.482	37,00	37,14	37,26	37,52	37,64
	0.995	1.519	1.524	1.529	1.534	1.539	38,45	38,59	38,71	38,97	39,09
	0.997	1.520	1.525	1.530	1.535	1.540	38,48	38,62	38,74	39,00	39,12
1	1.000	1.522	1.527	1.532	1.537	1.542	38,53	38,67	38,79	39,05	39,17
	1.003	1.523	1.528	1.533	1.538	1.543	38,55	38,69	38,81	39,07	39,19
	1.005	1.524	1.529	1.534	1.539	1.544	38,58	38,72	38,84	39,10	39,22

CWS-10H-A
Arc Gap Gage Dia. 50,65 mm

Nominal OD (mm)	Actual OD (mm)	Setting for 0,50 mm Arc Gap (mm)	Setting for 0,64 mm Arc Gap (mm)	Setting for 0,76 mm Arc Gap (mm)	Setting for 1,02 mm Arc Gap (mm)	Setting for 1,14 mm Arc Gap (mm)
	5,87	28,76	28,90	29,02	29,28	29,40
	5,94	28,80	28,94	29,06	29,32	29,44
6	6,00	28,83	28,97	29,09	29,35	29,47
	6,05	28,85	28,99	29,11	29,37	29,49
	6,12	28,89	29,03	29,15	29,41	29,53
	7,87	29,76	29,90	30,02	30,28	30,40
	7,92	29,80	29,94	30,06	30,32	30,44
8	8,00	29,83	29,97	30,09	30,35	30,47
	8,08	29,87	30,01	30,13	30,39	30,51
	8,13	29,89	30,03	30,15	30,41	30,53
	9,88	30,77	30,91	31,03	31,29	31,41
	9,92	30,79	30,93	31,05	31,31	31,43
10	10,00	30,83	30,97	31,09	31,35	31,47
	10,08	30,87	31,01	31,13	31,39	31,51
	10,14	30,90	31,04	31,16	31,42	31,54
	11,86	31,76	31,90	32,02	32,28	32,40
	11,92	31,80	31,94	32,06	32,32	32,44
12	12,00	31,83	31,97	32,09	32,35	32,47
	12,07	31,86	32,00	32,12	32,38	32,50
	12,12	31,89	32,03	32,15	32,41	32,53
	17,88	34,77	34,91	35,03	35,29	35,41
	17,92	34,79	34,93	35,05	35,31	35,43
18	18,00	34,83	34,97	35,09	35,35	35,47
	18,09	34,87	35,01	35,13	35,39	35,51
	18,14	34,90	35,04	35,16	35,42	35,54
	21,87	36,76	36,90	37,02	37,28	37,40
	21,92	36,79	36,93	37,05	37,31	37,43
22	22,00	36,83	36,97	37,09	37,35	37,47
	22,07	36,86	37,00	37,12	37,38	37,50
	22,12	36,89	37,03	37,15	37,41	37,53
	22,89	37,27	37,41	37,53	37,79	37,91
	22,94	37,30	37,44	37,56	37,82	37,94
23	23,00	37,33	37,47	37,59	37,85	37,97
	23,09	37,37	37,51	37,63	37,89	38,01
	23,14	37,40	37,54	37,66	37,92	38,04
	24,87	38,26	38,40	38,52	38,78	38,90
	24,94	38,30	38,44	38,56	38,82	38,94
25	25,00	38,33	38,47	38,59	38,85	38,97
	25,07	38,36	38,50	38,62	38,88	39,00
	25,12	38,39	38,53	38,65	38,91	39,03

CWS-20H-A/B
Arc Gap Gage Dia. 3.118 in.

Nominal OD (in.)	Actual OD (in.)	Setting for 0.025 in. Arc Gap (in.)	Setting for 0.030 in. Arc Gap (in.)	Setting for 0.035 in. Arc Gap (in.)	Setting for 0.040 in. Arc Gap (in.)	Setting for 0.045 in. Arc Gap (in.)	Setting for 0,50 mm Arc Gap (mm)	Setting for 0,64 mm Arc Gap (mm)	Setting for 0,76 mm Arc Gap (mm)	Setting for 1,02 mm Arc Gap (mm)	Setting for 1,14 mm Arc Gap (mm)
	0.495	1.832	1.837	1.842	1.847	1.852	46,39	46,53	46,65	46,91	47,03
	0.497	1.833	1.838	1.843	1.848	1.853	46,41	46,55	46,67	46,93	47,05
1/2	0.500	1.834	1.839	1.844	1.849	1.854	46,45	46,59	46,71	46,97	47,09
	0.503	1.836	1.841	1.846	1.851	1.856	46,49	46,63	46,75	47,01	47,13
	0.505	1.837	1.842	1.847	1.852	1.857	46,52	46,66	46,78	47,04	47,16
	0.745	1.957	1.962	1.967	1.972	1.977	49,56	49,70	49,82	50,08	50,20
	0.747	1.958	1.963	1.968	1.973	1.978	49,59	49,73	49,85	50,11	50,23
3/4	0.750	1.959	1.964	1.969	1.974	1.979	49,63	49,77	49,89	50,15	50,27
	0.753	1.961	1.966	1.971	1.976	1.981	49,66	49,80	49,92	50,18	50,30
	0.755	1.962	1.967	1.972	1.977	1.982	49,69	49,83	49,95	50,21	50,33
	0.995	2.082	2.087	2.092	2.097	2.102	52,74	52,88	53,00	53,26	53,38
	0.997	2.083	2.088	2.093	2.098	2.103	52,76	52,90	53,02	53,28	53,40
1	1.000	2.084	2.089	2.094	2.099	2.104	52,80	52,94	53,06	53,32	53,44
	1.003	2.086	2.091	2.096	2.101	2.106	52,84	52,98	53,10	53,36	53,48
	1.005	2.087	2.092	2.097	2.102	2.107	52,87	53,01	53,13	53,39	53,51
	1.245	2.207	2.212	2.217	2.222	2.227	55,91	56,05	56,17	56,43	56,55
	1.247	2.208	2.213	2.218	2.223	2.228	55,94	56,08	56,20	56,46	56,58
1 1/4	1.250	2.209	2.214	2.219	2.224	2.229	55,98	56,12	56,24	56,50	56,62
	1.253	2.211	2.216	2.221	2.226	2.231	56,01	56,15	56,27	56,53	56,65
	1.255	2.212	2.217	2.222	2.227	2.232	56,04	56,18	56,30	56,56	56,68
	1.495	2.332	2.337	2.342	2.347	2.352	59,09	59,23	59,35	59,61	59,73
	1.497	2.333	2.338	2.343	2.348	2.353	59,11	59,25	59,37	59,63	59,75
1 1/2	1.500	2.334	2.339	2.344	2.349	2.354	59,15	59,29	59,41	59,67	59,79
	1.503	2.336	2.341	2.346	2.351	2.356	59,19	59,33	59,45	59,71	59,83
	1.505	2.337	2.342	2.347	2.352	2.357	59,22	59,36	59,48	59,74	59,86
	1.995	2.582	2.587	2.592	2.597	2.602	65,44	65,58	65,70	65,96	66,08
	1.997	2.583	2.588	2.593	2.598	2.603	65,46	65,60	65,72	65,98	66,10
2	2.000	2.584	2.589	2.594	2.599	2.604	65,50	65,64	65,76	66,02	66,14
	2.003	2.586	2.591	2.596	2.601	2.606	65,54	65,68	65,80	66,06	66,18
	2.005	2.587	2.592	2.597	2.602	2.607	65,57	65,71	65,83	66,09	66,21

CWS-20H-A/B
Arc Gap Gage Dia. 79,23 mm

Nominal OD (mm)	Actual OD (mm)	Setting for 0,50 mm Arc Gap (mm)	Setting for 0,64 mm Arc Gap (mm)	Setting for 0,76 mm Arc Gap (mm)	Setting for 1,02 mm Arc Gap (mm)	Setting for 1,14 mm Arc Gap (mm)
12	11,86	46,05	46,19	46,31	46,57	46,69
	11,92	46,08	46,22	46,34	46,60	46,72
	12,00	46,12	46,26	46,38	46,64	46,76
	12,07	46,15	46,29	46,41	46,67	46,79
	12,12	46,17	46,31	46,43	46,69	46,81
18	17,88	49,06	49,20	49,32	49,58	49,70
	17,92	49,09	49,23	49,35	49,61	49,73
	18,00	49,12	49,26	49,38	49,64	49,76
	18,09	49,16	49,30	49,42	49,68	49,80
	18,14	49,18	49,32	49,44	49,70	49,82
22	21,87	51,05	51,19	51,31	51,57	51,69
	21,92	51,08	51,22	51,34	51,60	51,72
	22,00	51,12	51,26	51,38	51,64	51,76
	22,07	51,15	51,29	51,41	51,67	51,79
	22,12	51,18	51,32	51,44	51,70	51,82
23	22,87	51,56	51,70	51,82	52,08	52,20
	22,92	51,58	51,72	51,84	52,10	52,22
	23,00	51,62	51,76	51,88	52,14	52,26
	23,09	51,66	51,80	51,92	52,18	52,30
	21,14	51,69	51,83	51,95	52,21	52,33
25	24,87	52,55	52,69	52,81	53,07	53,19
	24,92	52,59	52,73	52,85	53,11	53,23
	25,00	52,62	52,76	52,88	53,14	53,26
	25,07	52,65	52,79	52,91	53,17	53,29
	25,12	52,68	52,82	52,94	53,20	53,32
28	27,86	54,05	54,19	54,31	54,57	54,69
	27,92	54,07	54,21	54,33	54,59	54,71
	28,00	54,12	54,26	54,38	54,64	54,76
	28,07	54,15	54,29	54,41	54,67	54,79
	28,12	54,17	54,31	54,43	54,69	54,81
35	34,87	57,55	57,69	57,81	58,07	58,19
	34,93	57,58	57,72	57,84	58,10	58,22
	35,00	57,62	57,76	57,88	58,14	58,26
	35,08	57,65	57,79	57,91	58,17	58,29
	35,13	57,68	57,82	57,94	58,20	58,32
52	51,87	66,05	66,19	66,31	66,57	66,69
	51,92	66,08	66,22	66,34	66,60	66,72
	52,00	66,12	66,26	66,38	66,64	66,76
	52,08	66,15	66,29	66,41	66,67	66,79
	52,13	66,18	66,32	66,44	66,70	66,82

Arc Gap Gage Setting Tables for Swagelok ATW Fittings

When using Swagelok ATW weld fittings shown in Figure E-23, measure the outside diameter of the integral filler ring or cuff. Use this cuff dimension in the proper table for Swagelok ATW fittings below, to determine the setting for the weld head model you are using.

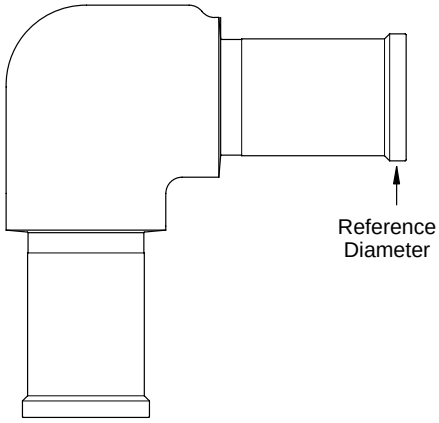


Figure E-23 Swagelok ATW Weld Fitting

CWS-5H-B
Arc Gap Gage Dia. 1.244 in. (31,60 mm)

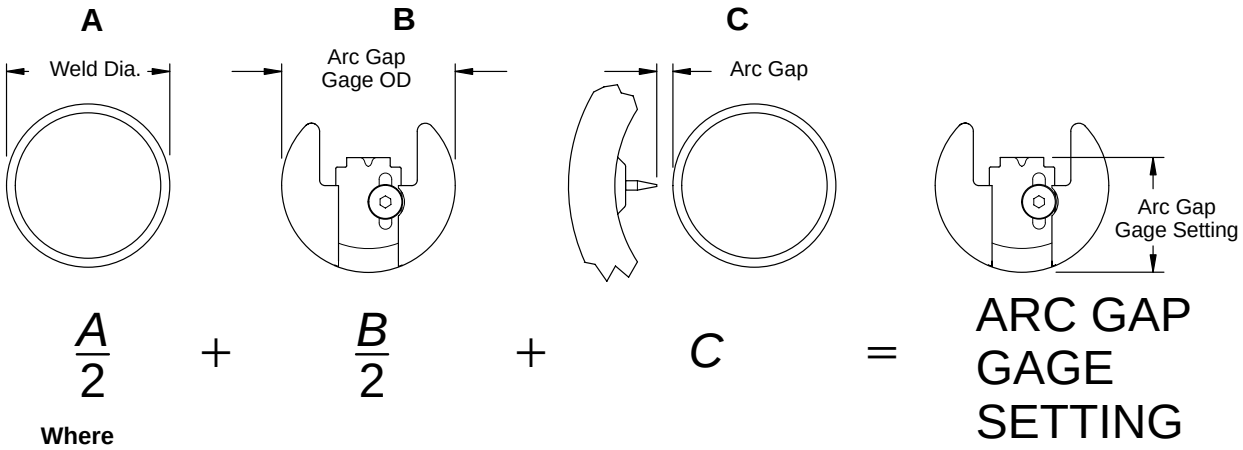
ATW Size	Cuff OD	Setting for 0.035 in. (0,89 mm) Arc Gap
1/4 in.	0.29 in.	0.801 in.
3/8 in.	0.41 in.	0.863 in.
1/2 in.	0.55 in.	0.931 in.
6 mm	7 mm	20,19 mm
8 mm	9 mm	21,20 mm
10 mm	11 mm	22,20 mm
12 mm	13,2 mm	23,32 mm

CWS-10H-A
Arc Gap Gage Dia. 1.944 in. (50,65 mm)

ATW Size	Cuff OD	Setting for 0.045 in. (1,14 mm) Arc Gap
1/4 in.	0.29 in.	1.186 in.
3/8 in.	0.41 in.	1.248 in.
1/2 in.	0.55 in.	1.316 in.
3/4 in.	0.8 in.	1.441 in.
1 in.	1.06 in.	1.571 in.
6 mm	7,0 mm	29,97 mm
8 mm	9,0 mm	30,98 mm
10 mm	11,0 mm	31,98 mm
12 mm	13,2 mm	33,10 mm
18 mm	19,2 mm	36,11 mm
23 mm	25,4 mm	38,5 mm

Arc Gap Gage Setting Formula

To determine the arc gap gage setting for a specific arc gap, use the formula below.



Where

A = largest OD on the weld end of the tubing or fitting (welding diameter).

B = Arc gap gage diameter

C = desired arc gap

Figure E-1 Arc Gap Gage Setting Formula

Example No. 1: (Series 5 Weld Head)

1/4 to 1/4 in. tube butt weld - largest outside diameter	A = 0.253 in.
Arc gap gage diameter	B = 1.244 in.
Desired arc gap	C = 0.028 in.

$$\frac{0.253 \text{ in.}}{2} + \frac{1.244 \text{ in.}}{2} + 0.028 \text{ in.} = 0.777 \text{ in.}$$

Example No. 2: (Series 5 Weld Head)

6 to 6 mm tube butt weld - largest outside diameter	A = 6,081 mm
Arc gap gage diameter	B = 31,60 mm
Desired arc gap	C = 0,71 mm

$$\frac{6,081 \text{ mm}}{2} + \frac{31,60 \text{ mm}}{2} + 0,71 \text{ mm} = 19,551 \text{ mm}$$

Appendix F
Parts Drawings

This section includes exploded assembly drawings and associated parts lists. These drawings are provided as a guide to identifying part names. For specific part ordering information, contact your Swagelok representative.

The parts identified in this section include:

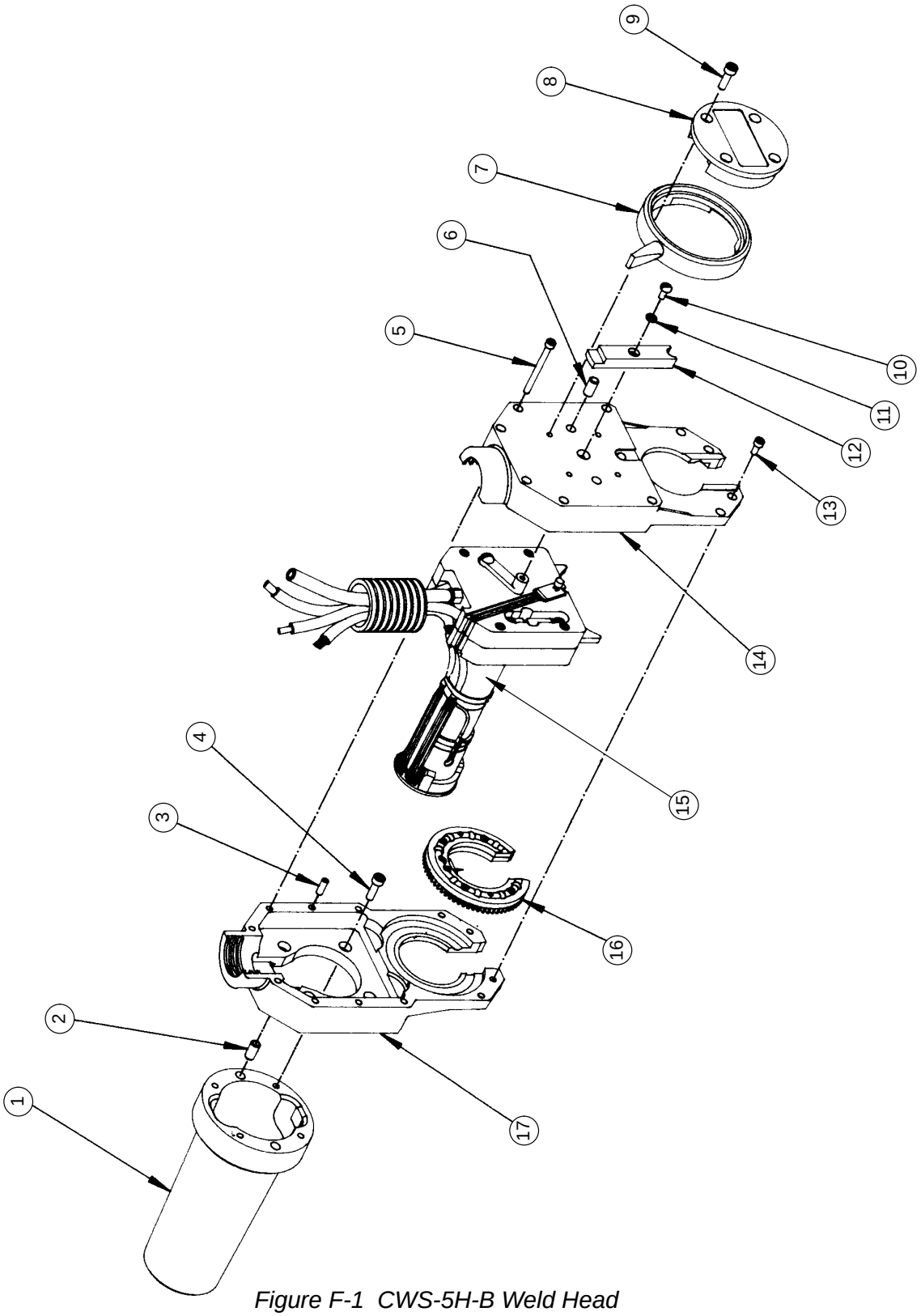


Figure F-1 CWS-5H-B Weld Head

Table F-1 CWS-5H-B Weld Head Parts List

Reference No.	Description	Available in Kit No. †
1	Motor Cover	CWS-11121-PKG
2	Motor Cover Pins	CWS-11121-PKG CWS-5WHA-PKG
3	Weld Head Housing Pins	CWS-5HP-MTRHOUSE CWS-5WHA-PKG
4	Motor Cover Screws	CWS-11121-PKG CWS-5WHA-PKG
5	Weld Head Housing Screws (long)	CWS-5HP-LOCHOUSE CWS-5WHA-PKG CWS-5HP-MTRHOUSE CWS-5HP-LOCHOUSEPL
6	Locking Ring Plate Pins	CWS-11104-PKG CWS-5WHA-PKG
7	Locking Ring with Handle	CWS-11106-1
8	Locking Ring Plate	CWS-11104-PKG
9	Locking Ring Screws	CWS-11104-PKG CWS-5WHA-PKG
10	Work(+) Extension Screw	CWS-11112-PKG CWS-5WHA-PKG CWS-13101-05
11	Work(+) Extension Washer	CWS-11112-PKG
12	Work(+) Extension	CWS-11112-PKG
13	Weld Head Housing Screws (short)	CWS-5HP-LOCHOUSE CWS-5WHA-PKG CWS-5HP-MTRHOUSE CWS-5HP-LOCHOUSEPL
14	Weld Head Housing (locking ring side)	CWS-5HP-LOCHOUSE CWS-5HP-LOCHOUSEPL
15	Motor and Power Block Assembly	*
16	Rotor Assembly	CWS-11051-SUB
17	Weld Head Housing (motor cover side)	CWS-5HP-MTRHOUSE

† For part ordering information, contact your Swagelok representative.
* Not available as a field replaceable spare part.

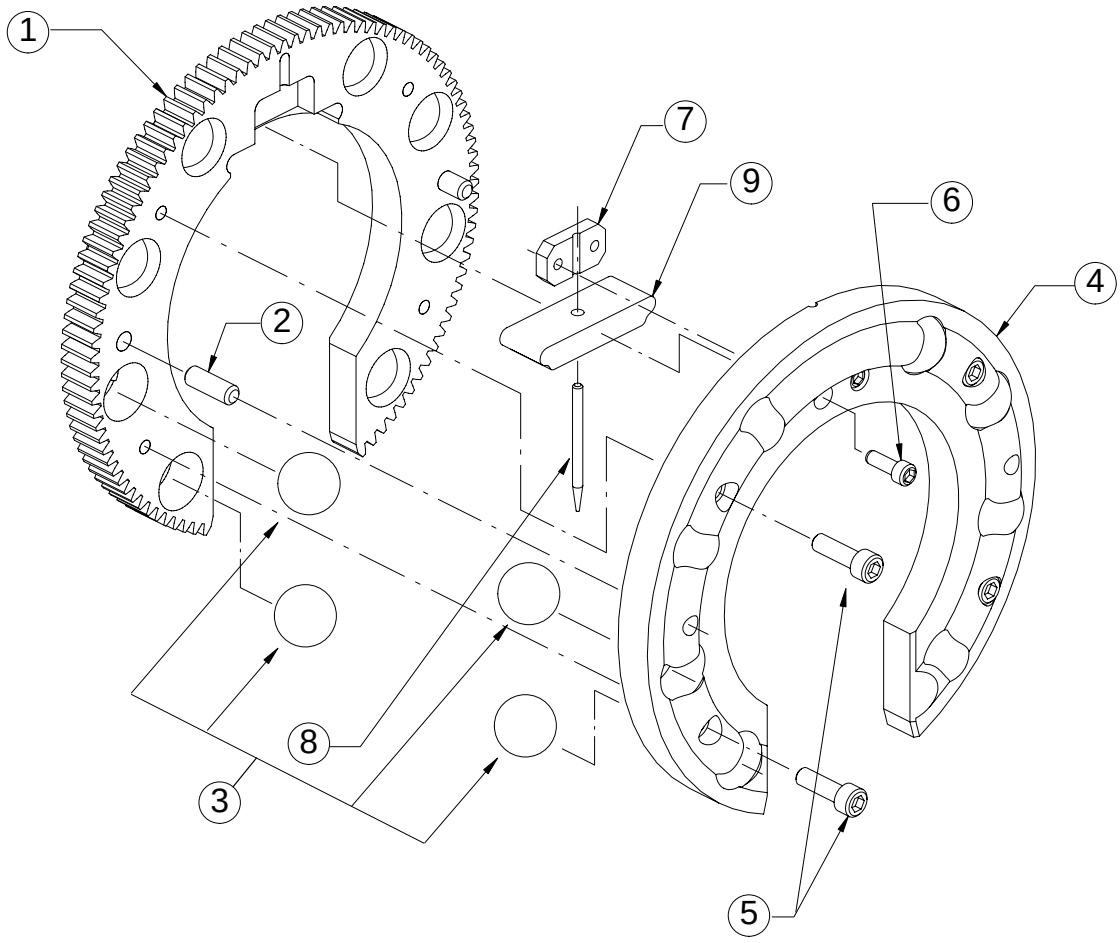


Figure F-2 Series 5/10/20 Rotor Assembly

Table F-2 Series 5/10/20 Rotor Assembly Parts List

Reference No.	Description	Available in Kit No. †
1	Gear Ring	CWS-11051-SUB CWS-11136-PKG, CWS-11056-SUB CWS-11062-SUB, CWS-11304-PKG
2	Dowel Pins	CWS-11051-SUB, CWS-5ROTOR-PKG, CWS-10ROTOR-PKG CWS-11136-PKG, CWS-11056-SUB CWS-20ROTOR-PKG, CWS-11304-PKG CWS-11062-SUB
3	Ball Bearings	CWS-11051-SUB, CWS-11153-16, CWS-11136-PKG CWS-11056-SUB, CWS-11154-16 CWS-11304-PKG, CWS-11062-SUB CWS-11154-20
4	Brush Ring	CWS-11051-SUB CWS-11136-PKG, CWS-11056-SUB CWS-11062-SUB, CWS-11304-PKG
5	Rotor Screws	CWS-11051-SUB, CWS-5ROTOR-PKG CWS-13111-10 CWS-10ROTOR-PKG, CWS-11056-SUB CWS-20ROTOR-PKG, CWS-11062-SUB
6	Electrode Clamping Plate Screws	CWS-11051-SUB, CWS-13110-06 CWS-11108-PKG, CWS-5ROTOR-PKG CWS-13176-06, CWS-11056-SUB CWS-11204-PKG, CWS-10ROTOR-PKG CWS-13176-06, CWS-11062-SUB CWS-11306-PKG, CWS-20ROTOR-PKG
7	Electrode Clamping Plate	CWS-11051-SUB, CWS-11108-PKG CWS-11204-PKG, CWS-11056-SUB CWS-11062-SUB, CWS-11306-PKG
8	Electrode	CWS-C.040-.705-P, CWS-C.040-.605-P, CWS-C.040-.555-P, CWS-C.062-.1.105-P, CWS-C.062-.855-P, CWS-C.062-.1.630-P, CWS-C.062-.1.380-P, CWS-C.062-.1.105-P
9	Ceramic Insert	CWS-11051-SUB, CWS-11132, CWS-11136-PKG CWS-11056-SUB, CWS-11210 CWS-11062-SUB, CWS-11304-PKG CWS-11210

† For part ordering information, contact your Swagelok representative.

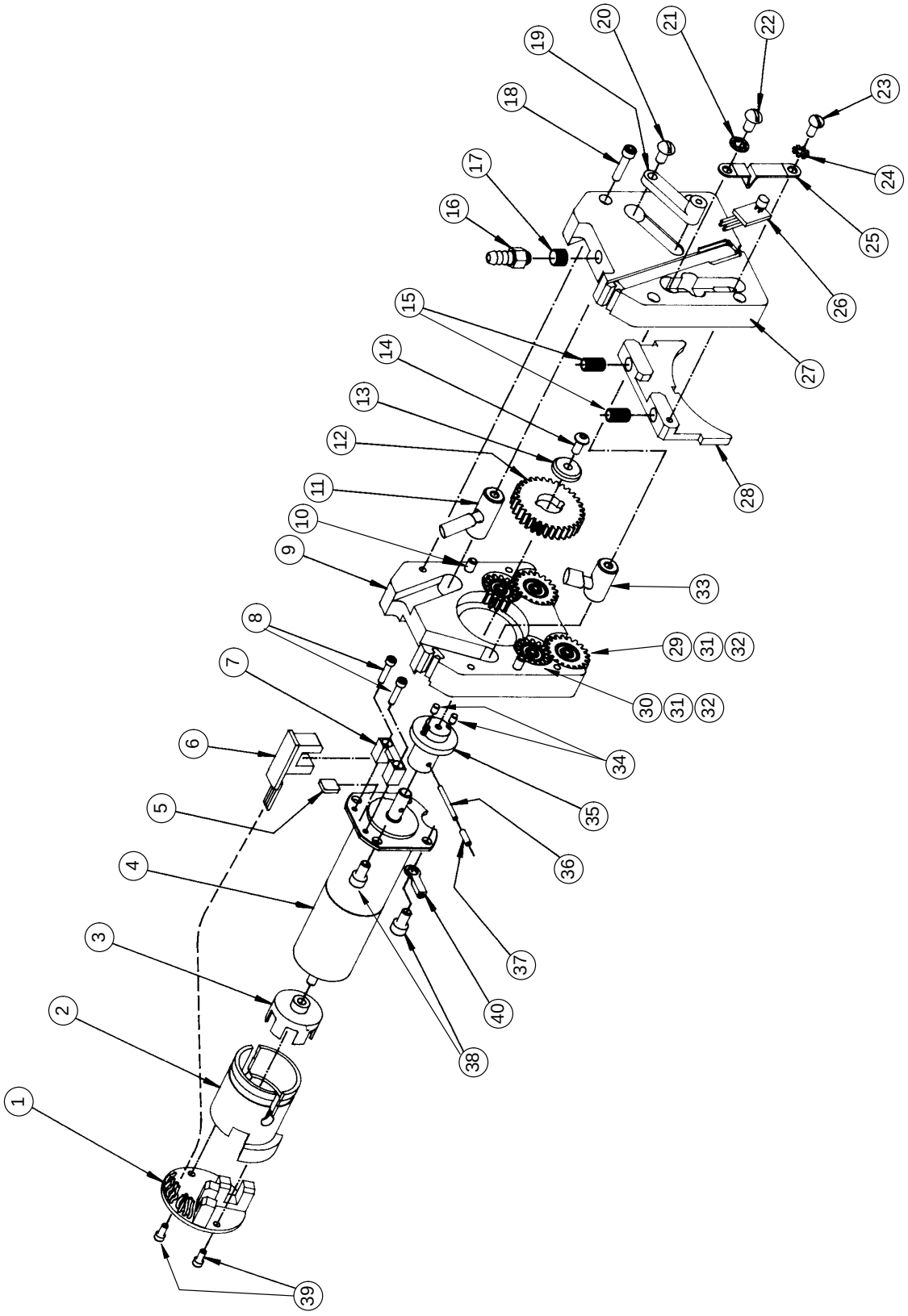


Figure F-3 CWS-5H-B Motor and Power Block Assembly

Table F-3 CWS-5H-B Motor and Power Block Assembly Parts List

Reference No.	Description	Available in Kit No. †
1	Encoder Board Assembly	*
2	Encoder Sleeve	*
3	Encoder Wheel	*
4	Motor	*
5	Spacer	*
6	Home Sensor Assembly	*
7	Sensor Mount	*
8	Sensor Mount Screws	*
9	Power Block Housing (motor side)	CWS-5PBH-PKG, CWS-5PBH-B-PKG
10	Power Block Pins	CWS-5PBH-PKG, CWS-5PBH-B-PKG CWS-5PBA-PKG
11	Work(+) Post	*
12	Drive Gear	CWS-11122-PKG
13	Drive Gear Washer	CWS-11122-PKG
14	Drive Gear Screw	CWS-11122-PKG
15	Brush Springs	CWS-11111-PKG, CWS-11157-02 CWS-5PBA-PKG
16	Gas Bayonet	CWS-5PBH-PKG CWS-5PBH-B-PKG
17	Thread Insert	CWS-5PBH-PKG CWS-5PBH-B-PKG
18	Power Block Screws	CWS-5PBH-PKG, CWS-5PBH-B-PKG CWS-5PBA-PKG
19	Work(+) Plate	CWS-11053-PKG
20	Work(+) Plate Screw	CWS-11053-PKG, CWS-5PBA-PKG
21	Power Strap Internal Star Washer	CWS-11117-PKG, CWS-5PBA-PKG
22	Power Strap Screw (large)	CWS-11117-PKG, CWS-5PBA-PKG
23	Power Strap Screw (small)	CWS-11117-PKG, CWS-5PBA-PKG
24	Power Strap External Star Washer	CWS-11117-PKG, CWS-5PBA-PKG
25	Power Strap	CWS-11117-PKG
26	Safety Interlock Sensor	*
27	Power Block Housing (brush side)	CWS-5PBH-PKG, CWS-5PBH-B-PKG
28	Brush	CWS-11111-PKG
29, 31, 32	Secondary Gear Assy (gear, bearing, gear pin)	CWS-11142-PKG
30, 31, 32	Primary Gear Assy (gear, bearing, gear pin)	CWS-11118-PKG
33	Electrode(−) Post	*
34	Drive Coupler Pins	CWS-11122-PKG
35	Drive Coupler	*
36	Drive Coupler Motor Pin	*
37	Sleeve	*
38	Motor Mounting Screws	CWS-5PBA-PKG
39	Encoder Board Mount Screws	*
40	Motor Ground Lug	*

† For part ordering information, contact your Swagelok representative.

* Not available as a field replaceable spare part.

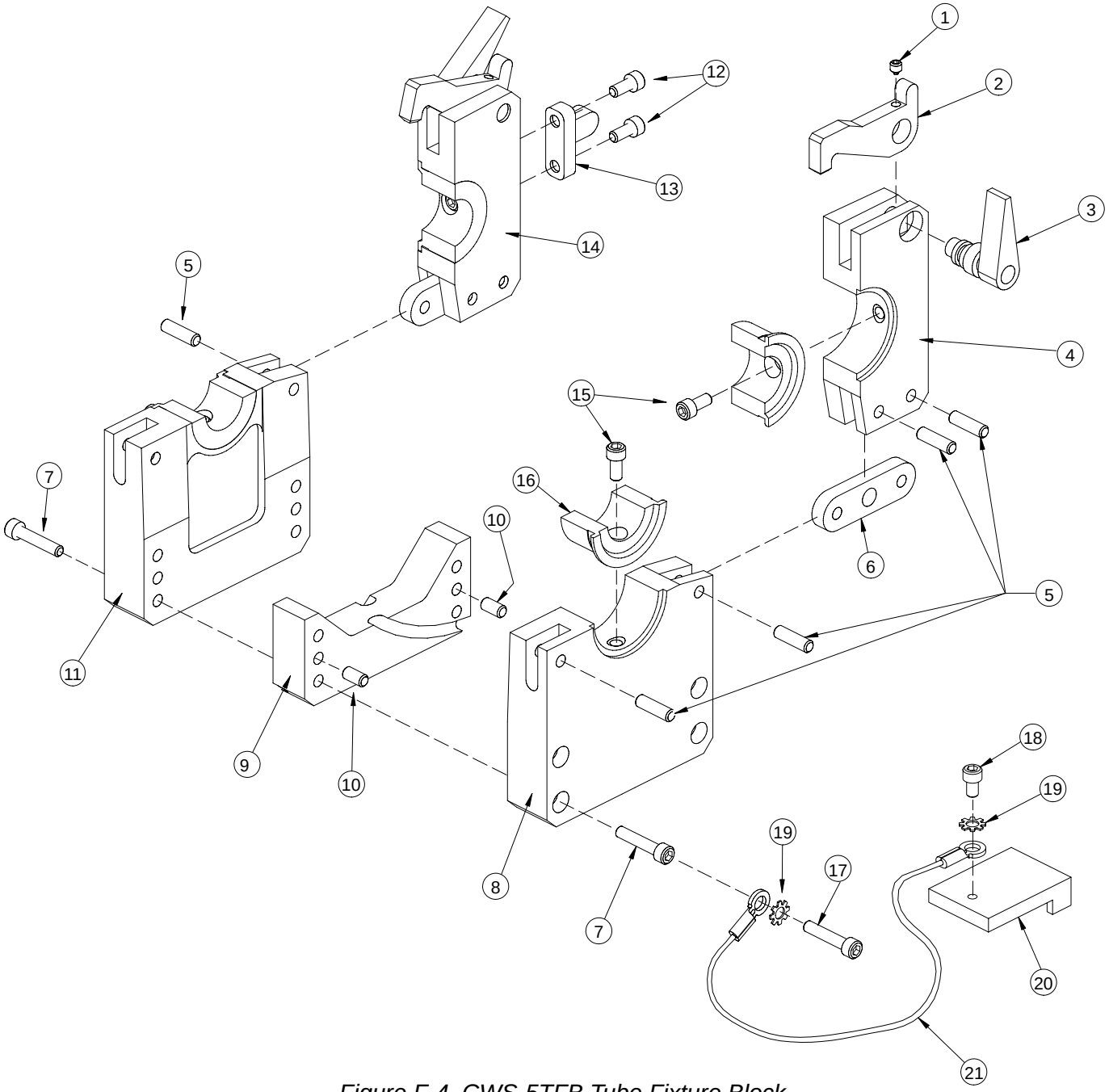


Figure F-4 CWS-5TFB Tube Fixture Block

Table F-4 CWS-5TFB Tube Fixture Block Parts List

Reference No.	Description	Available in Kit No. †
1	Latch Screw	CWS-12132-02 CWS-12131-PKG CWS-5FIX-PKG
2	Latch	CWS-12131-PKG
3	Lever Cam Assembly	CWS-12130-2
4	Top Side Plate (right)	*
5	Hinge and Latch Pins	CWS-5FIX-PKG
6	Hinge	*
7	Side Plate Screws	CWS-5FIX-PKG
8	Bottom Side Plate (right)	*
9	Plenum	CWS-5PLEN
10	Plenum Pins	CWS-5FIX-PKG
11	Bottom Side Plate (left)	*
12	Locking Ring Tab Screws	CWS-12134-PKG CWS-5FIX-PKG
13	Locking Ring Tab	CWS-12134-PKG
14	Top Side Plate (left)	*
15	Collet Insert Screws	CWS-5FIX-PKG CWS-13112-04
16	Collet Insert	†
17	Lanyard Screw (long, side plate)	CWS-5CG
18	Lanyard Screw (short, centering gage)	CWS-5CG
19	Lanyard Star Washer	CWS-5CG
20	Centering Gage	CWS-5CG
21	Lanyard	CWS-5CG

† For part ordering information, contact your Swagelok representative.
* Not available as a field replaceable spare part.

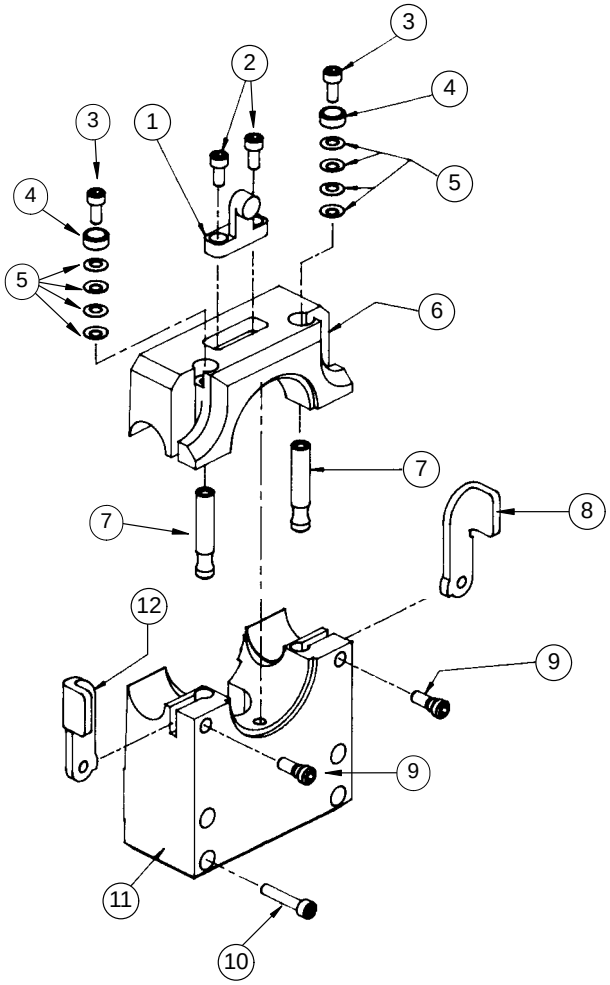


Figure F-5 CWS-5FSP1 Special Purpose Fixture Block

Table F-5 CWS-5FSP1 Special Purpose Fixture Block Parts List

Reference No.	Description	Available in Kit No. †
1	Locking Ring Tab	CWS-12134-PKG
2	Locking Ring Tab Screws	CWS-12134-PKG CWS-5FIX-PKG CWS-13112-04
3	Socket Head Screw	CWS-12158L-PKG CWS-12159R-PKG CWS-13112-04
4	Spacer	*
5	Spring Washers	*
6	Top Side Plate	*
7	Latch Cam Pin	CWS-12158L-PKG CWS-12159R-PKG
8	Right Latch Cam	CWS-12159R-PKG CWS-5FIX-PKG
9	Latch Cam Set Screw	CWS-12158L-PKG CWS-12159R-PKG
10	Side Plate Screws	CWS-5FIX-PKG
11	Bottom Side Plate	*
12	Left Latch Cam	CWS-12158L-PKG

† For part ordering information, contact your Swagelok representative.
* Not available as a field replaceable spare part.

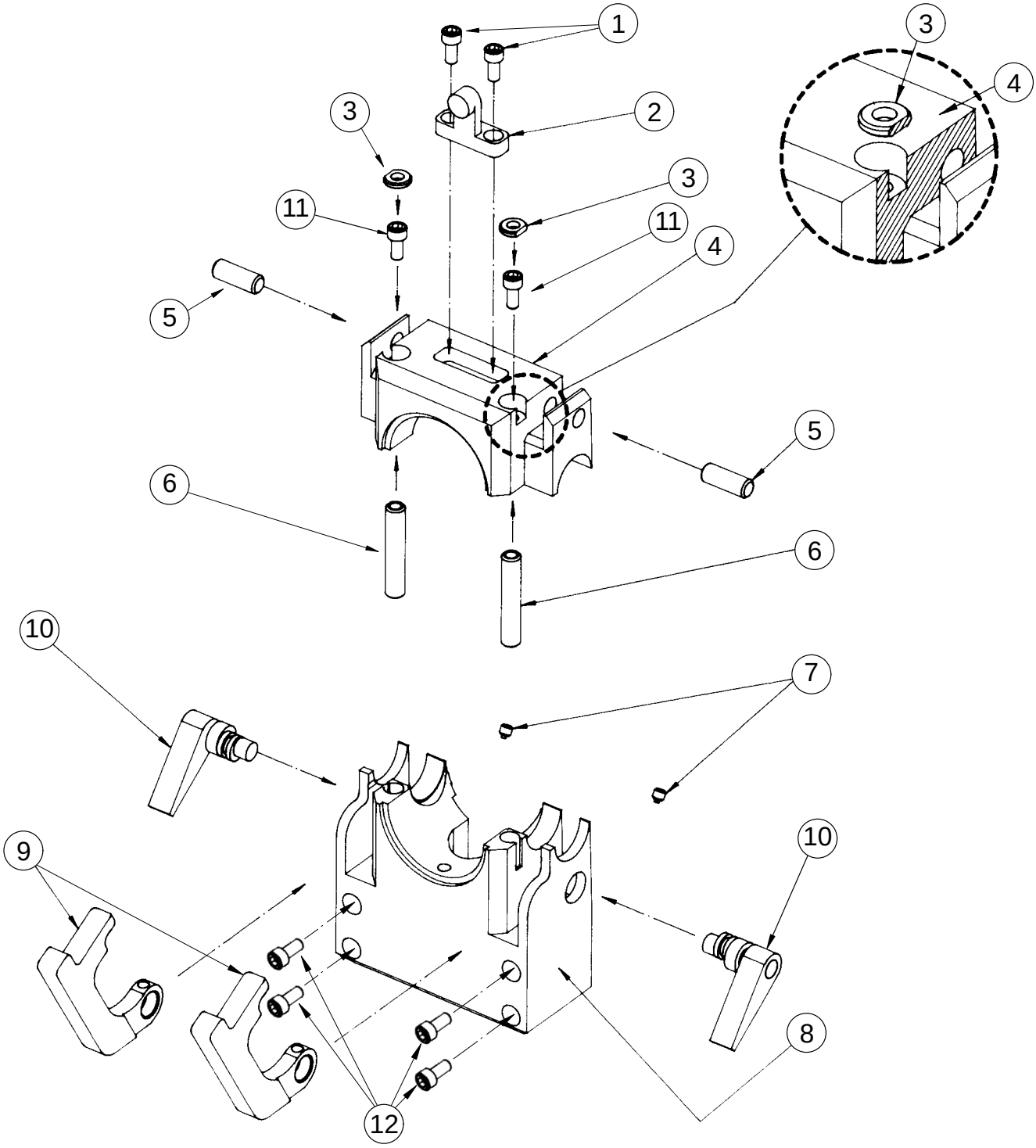


Figure F-6 CWS-5FSP2 Special Purpose Fixture Block

Table F-6 CWS-5FSP2 Special Purpose Fixture Block Parts List

Reference No.	Description	Available in Kit No. †
1	Locking Ring Tab Screws	CWS-12134-PKG CWS-13112-04
2	Locking Ring Tab	CWS-12134-PKG
3	Screw Retainer	CWS-5FP-FSP2RETAIN
4	Top Side Plate	*
5	Dowel Pin	*
6	Locator Pin	*
7	Latch Cam Set Screw	CWS-12132-02 CWS-5FP-FSP2LATCH
8	Bottom Side Plate	*
9	Latch	CWS-5FP-FSP2LATCH
10	Lever Cam Assembly	CWS-12130-2
11	Socket Head Screw	CWS-13112-04
12	Socket Head Screw	CWS-5FIX-PKG

† For part ordering information, contact your Swagelok representative.
* Not available as a field replaceable spare part.

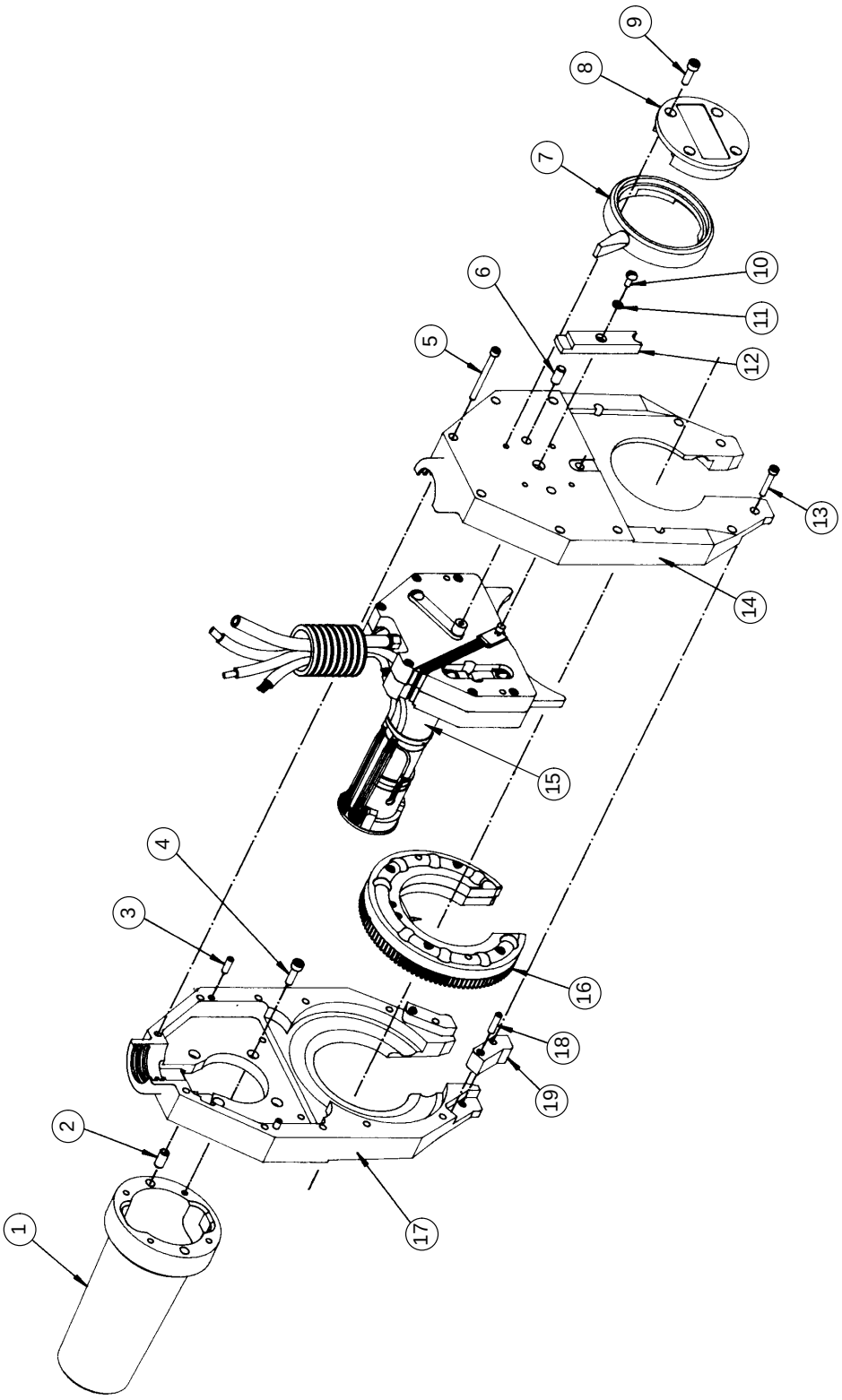


Figure F-7 CWS-10H-A Weld Head

Table F-7 CWS-10H-A Weld Head Parts List

Reference No.	Description	Available in Kit No. †
1	Motor Cover	CWS-11121-PKG
2	Motor Cover Pins	CWS-11121-PKG CWS-10WHA-PKG
3	Weld Head Housing Pins	CWS-10HP-MTRHOUSE CWS-10WHA-PKG
4	Motor Cover Screws	CWS-11121-PKG CWS-10WHA-PKG
5	Weld Head Housing Screws (long)	CWS-10HP-LOCHOUSE CWS-10WHA-PKG CWS-10HP-MTRHOUSE CWS-10HP-LOCHOUSEPL
6	Locking Ring Plate Pins	CWS-11104-PKG CWS-10WHA-PKG
7	Locking Ring with Handle	CWS-11106-1
8	Locking Ring Plate	CWS-11104-PKG
9	Locking Ring Plate Screws	CWS-11104-PKG CWS-10WHA-PKG
10	Work(+) Extension Screw	CWS-11112-PKG CWS-13101-05
11	Work(+) Extension Washer	CWS-11112-PKG
12	Work(+) Extension	CWS-11112-PKG
13	Weld Head Housing Screws (short)	CWS-10HP-LOCHOUSE CWS-10WHA-PKG CWS-10HP-MTRHOUSE CWS-10HP-LOCHOUSEPL
14	Weld Head Housing (locking ring side)	CWS-10HP-LOCHOUSE CWS-10HP-LOCHOUSEPL
15	Motor and Power Block Assembly	*
16	Rotor Assembly	CWS-11056-SUB
17	Weld Head Housing (motor cover side)	CWS-10HP-MTRHOUSE
18	Bearing Pad Pins	CWS-10HP-BEARINGPAD
19	Bearing Pad	CWS-10HP-BEARINGPAD

† For part ordering information, contact your Swagelok representative.
* Not available as a field replaceable spare part.

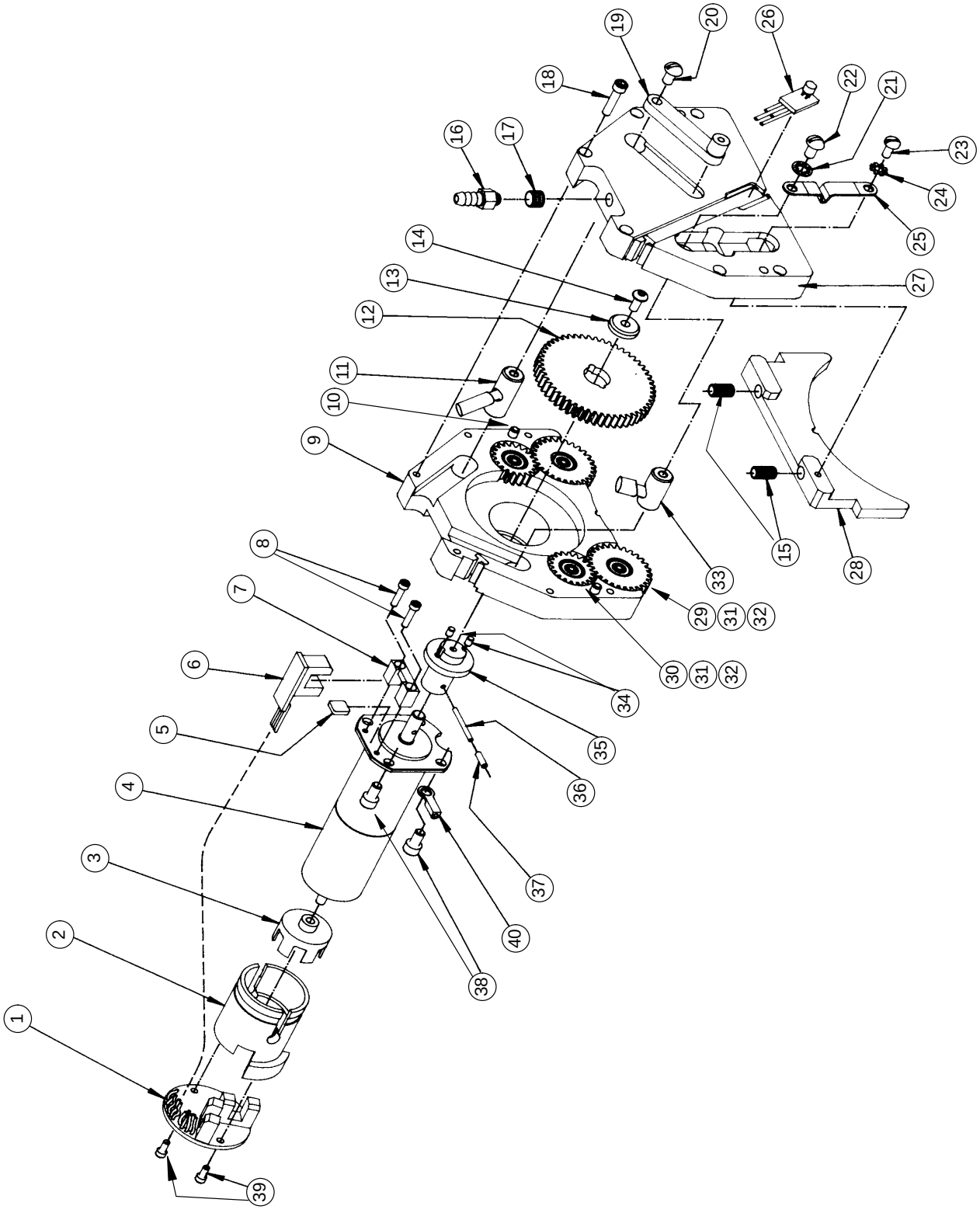


Figure F-8 CWS-10H-A Motor and Power Block Assembly

Table F-8 CWS-10H-A Motor and Power Block Assembly Parts List

Reference No.	Description	Available in Kit No. †
1	Encoder Board Assembly	*
2	Encoder Sleeve	*
3	Encoder Wheel	*
4	Motor	*
5	Spacer	*
6	Home Sensor Assembly	*
7	Sensor Mount	*
8	Sensor Mount Screws	*
9	Power Block Housing (motor side)	CWS-10PBH-PKG, CWS-10PBH-A-PKG
10	Power Block Pins	CWS-10PBH-PKG, CWS-10PBH-A-PKG CWS-10PBA-PKG
11	Work(+) Post	*
12	Drive Gear	CWS-11156-PKG
13	Drive Gear Washer	CWS-11156-PKG
14	Drive Gear Screw	CWS-11156-PKG
15	Brush Springs	CWS-11137-PKG, CWS-11157-02 CWS-10PBA-PKG
16	Gas Bayonet	CWS-10PBH-PKG, CWS-10PBH-A-PKG
17	Thread Insert	CWS-10PBH-PKG, CWS-10PBH-A-PKG
18	Power Block Screws	CWS-10PBH-PKG, CWS-10PBH-A-PKG CWS-10PBA-PKG
19	Work(+) Plate	CWS-11054-PKG
20	Work(+) Plate Screw	CWS-11054-PKG, CWS-10PBA-PKG
21	Power Strap Internal Star Washer	CWS-11117-PKG, CWS-10PBA-PKG
22	Power Strap Screw (large)	CWS-11117-PKG, CWS-10PBA-PKG
23	Power Strap Screw (small)	CWS-11117-PKG, CWS-10PBA-PKG
24	Power Strap External Star Washer	CWS-11117-PKG, CWS-10PBA-PKG
25	Power Strap	CWS-11117-PKG
26	Safety Interlock Sensor	*
27	Power Block Housing (brush side)	CWS-10PBH-PKG, CWS-10PBH-A-PKG
28	Brush	CWS-11137-PKG
29, 31, 32	Secondary Gear Assy (gear, bearing, gear pin)	CWS-11141-PKG
30, 31, 32	Primary Gear Assy (gear, bearing, gear pin)	CWS-11142-PKG
33	Electrode(−) Post	*
34	Drive Coupler Pins	CWS-11156-PKG
35	Drive Coupler	*
36	Drive Coupler Motor Pin	*
37	Sleeve	*
38	Motor Mounting Screws	CWS-10PBA-PKG
39	Encoder Board Mount Screws	*
40	Motor Ground Lug	*

† For part ordering information, contact your Swagelok representative.

* Not available as a field replaceable spare part.

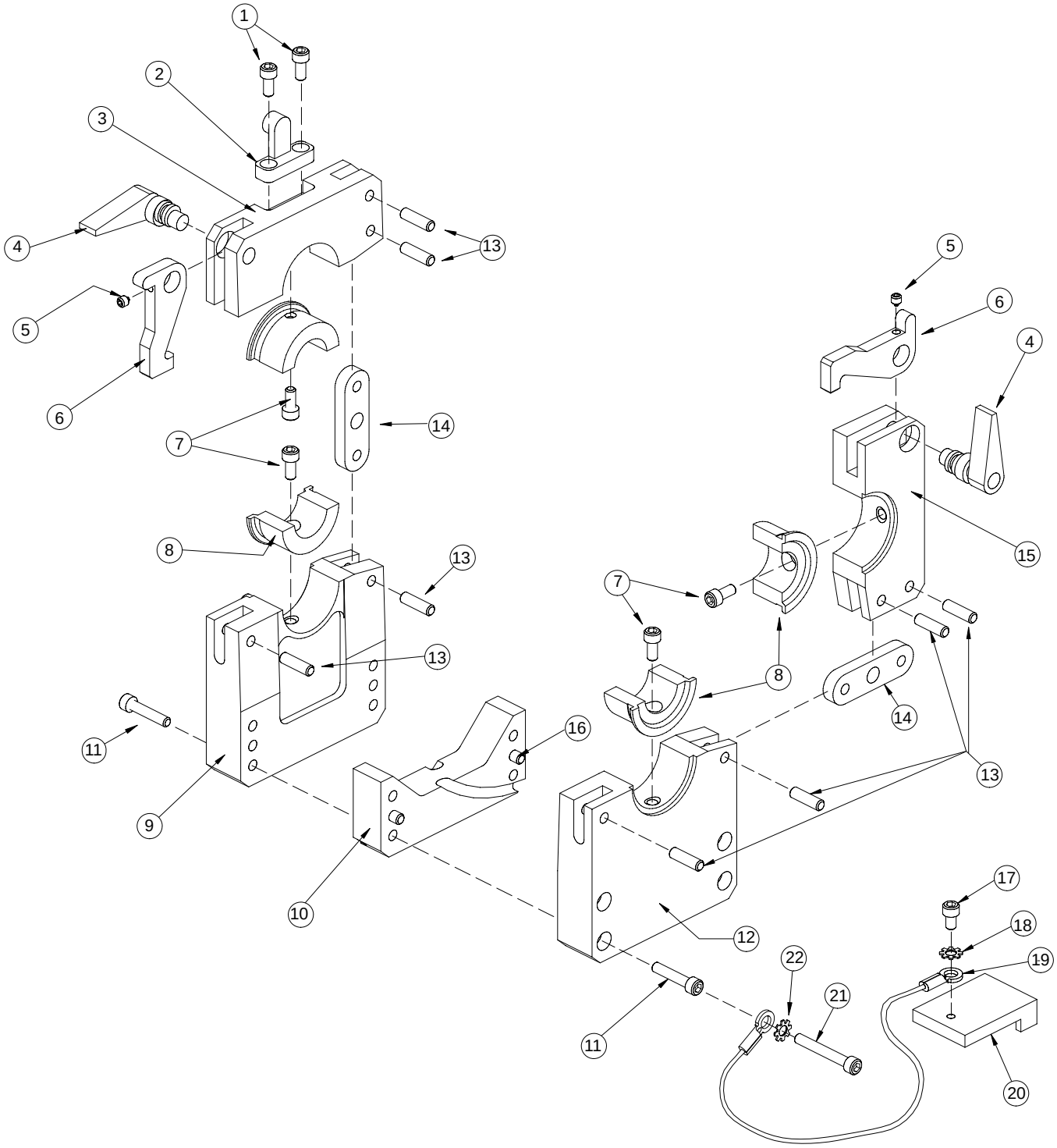


Figure F-9 CWS-10TFB Tube Fixture Block

Table F-9 CWS-10TFB Tube Fixture Block Parts List

Reference No.	Description	Available in Kit No. †
1	Locking Ring Tab Screws	CWS-12148-PKG CWS-10FIX-PKG
2	Locking Ring Tab	CWS-12148-PKG
3	Top Side Plate (left)	*
4	Lever Cam Assembly	CWS-12130-2
5	Latch Screw	CWS-12132-02 CWS-12146-PKG CWS-10FIX-PKG
6	Latch	CWS-12146-PKG
7	Collet Insert Screws	CWS-10FIX-PKG, CWS-13112-04
8	Collet Insert	†
9	Bottom Side Plate (left)	*
10	Plenum	CWS-10PLEN
11	Side Plate Screws	CWS-10FIX-PKG
12	Bottom Side Plate (right)	*
13	Hinge and Latch Pins	CWS-10FIX-PKG
14	Hinge	*
15	Top Side Plate (right)	*
16	Plenum Pins	CWS-10FIX-PKG
17	Lanyard Screw (short, centering gage)	CWS-10CG
18	Lanyard Star Washer	CWS-10CG
19	Lanyard	CWS-10CG
20	Centering Gage	CWS-10CG
21	Lanyard Screw (long, side plate)	CWS-10CG
22	Lanyard Star Washer	CWS-10CG

† For part ordering information, contact your Swagelok representative.
* Not available as a field replaceable spare part.

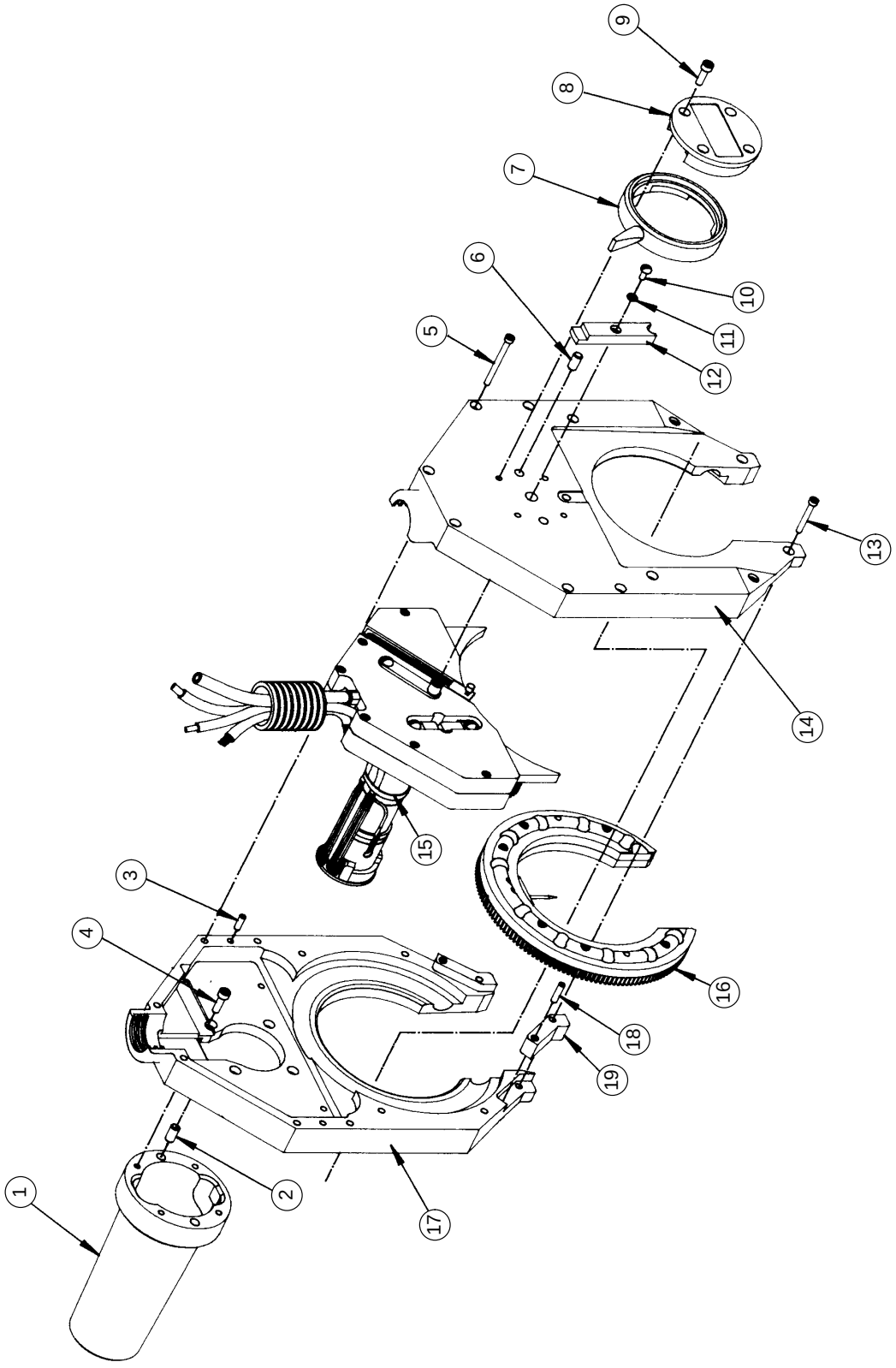


Figure F-10 CWS-20H-A Weld Head

Table F-10 CWS-20H-A Weld Head Parts List

Reference No.	Description	Available in Kit No. †
1	Motor Cover	CWS-11121-PKG
2	Motor Cover Pins	CWS-11121-PKG CWS-20WHA-PKG
3	Weld Head Housing Pins	CWS-20HP-MTRHOUSE CWS-20WHA-PKG
4	Motor Cover Screws	CWS-11121-PKG CWS-20WHA-PKG
5	Weld Head Housing Screws (long)	CWS-20HP-LOCHOUSE CWS-20WHA-PKG CWS-20HP-MTRHOUSE CWS-20HP-LOCHOUSEPL
6	Locking Ring Plate Pins	CWS-11104-PKG CWS-20WHA-PKG
7	Locking Ring with Handle	CWS-11106-1
8	Locking Ring Plate	CWS-11104-PKG
9	Locking Ring Plate Screws	CWS-11104-PKG CWS-20WHA-PKG
10	Work(+) Extension Screw	CWS-11112-PKG CWS-13101-05
11	Work(+) Extension Washer	CWS-11112-PKG
12	Work(+) Extension	CWS-11112-PKG
13	Weld Head Housing Screws (short)	CWS-20HP-LOCHOUSE CWS-20WHA-PKG CWS-20HP-MTRHOUSE CWS-20HP-LOCHOUSEPL
14	Weld Head Housing (locking ring side)	CWS-20HP-LOCHOUSE CWS-20HP-LOCHOUSEPL
15	Motor and Power Block Assembly	*
16	Rotor Assembly	CWS-11062-SUB
17	Weld Head Housing (motor cover side)	CWS-20HP-MTRHOUSE
18	Bearing Pad Pins	CWS-20HP-BEARINGPAD
19	Bearing Pad	CWS-20HP-BEARINGPAD

† For part ordering information, contact your Swagelok representative.
* Not available as a field replaceable spare part.

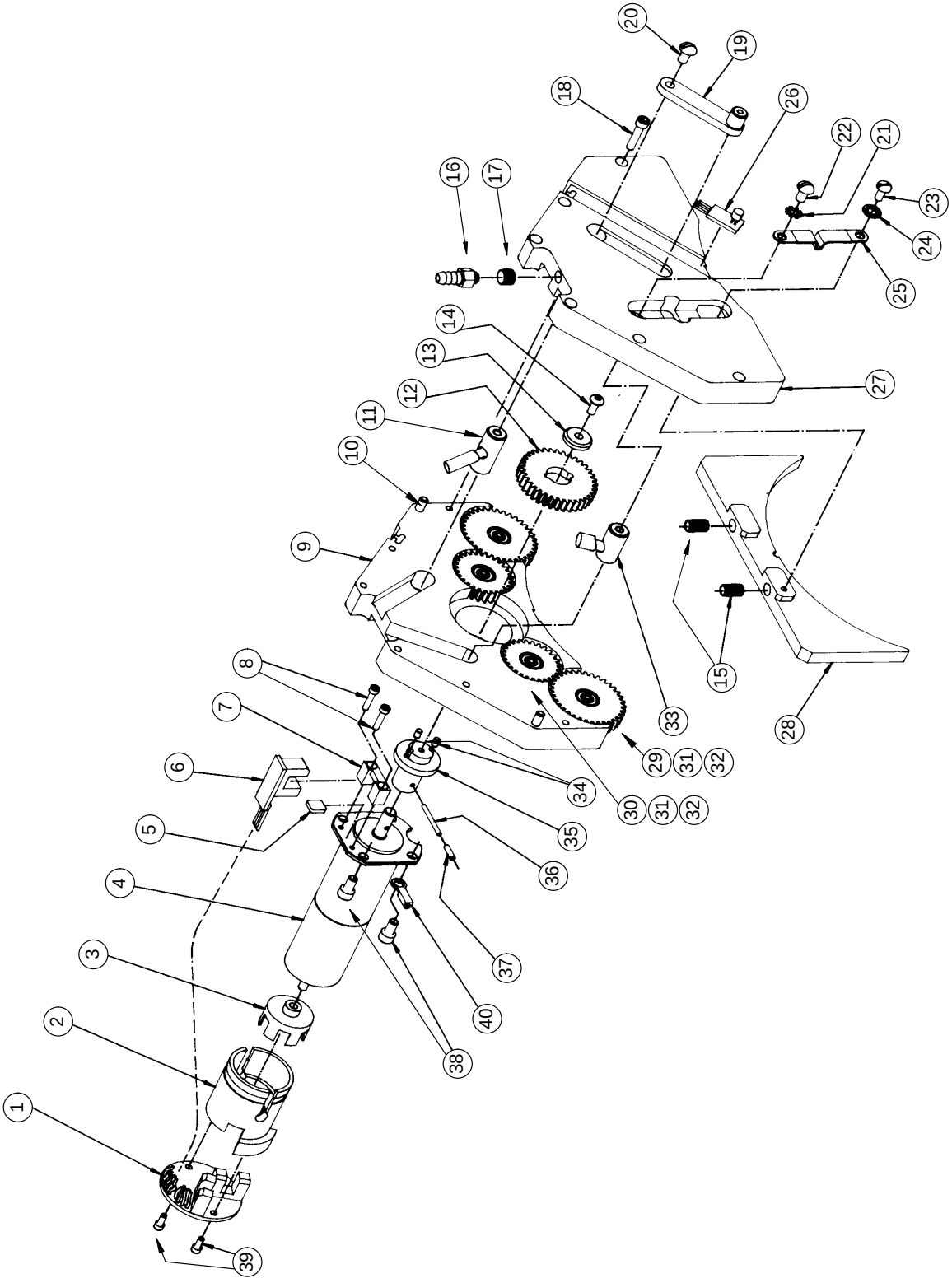


Figure F-11 CWS-20H-A Motor and Power Block Assembly

Table F-11 CWS-20H-A Motor and Power Block Assembly Parts List

Reference No.	Description	Available in Kit No. †
1	Encoder Board Assembly	*
2	Encoder Sleeve	*
3	Encoder Wheel	*
4	Motor	*
5	Spacer	*
6	Home Sensor Assembly	*
7	Sensor Mount	*
8	Sensor Mount Screws	*
9	Power Block Housing (motor side)	CWS-20PBH-PKG, CWS-20PBH-A-PKG
10	Power Block Pins	CWS-20PBH-PKG, CWS-20PBH-A-PKG CWS-20PBA-PKG
11	Work(+) Post	*
12	Drive Gear	CWS-11315-PKG
13	Drive Gear Washer	CWS-11315-PKG
14	Drive Gear Screw	CWS-11315-PKG
15	Brush Springs	CWS-11305-PKG, CWS-11205-02 CWS-20PBA-PKG
16	Gas Bayonet	CWS-20PBH-PKG, CWS-20PBH-A-PKG
17	Thread Insert	CWS-20PBH-PKG, CWS-20PBH-A-PKG
18	Power Block Screws	CWS-20PBH-PKG, CWS-20PBH-A-PKG CWS-20PBA-PKG
19	Work(+) Plate	CWS-11060-PKG
20	Work(+) Plate Screw	CWS-11060-PKG, CWS-20PBA-PKG
21	Power Strap Internal Star Washer	CWS-11117-PKG
22	Power Strap Screw (large)	CWS-11117-PKG, CWS-20PBA-PKG
23	Power Strap Screw (small)	CWS-11117-PKG, CWS-20PBA-PKG
24	Power Strap External Star Washer	CWS-11117-PKG
25	Power Strap	CWS-11117-PKG
26	Safety Interlock Sensor	*
27	Power Block Housing (brush side)	CWS-20PBH-PKG, CWS-20PBH-A-PKG
28	Brush	CWS-11305-PKG
29, 31, 32	Secondary Gear Assy (gear, bearing, gear pin)	CWS-11313-PKG
30, 31, 32	Primary Gear Assy (gear, bearing, gear pin)	CWS-11141-PKG
33	Electrode(−) Post	*
34	Drive Coupler Pins	CWS-11315-PKG
35	Drive Coupler	*
36	Drive Coupler Motor Pin	*
37	Sleeve	*
38	Motor Mounting Screws	CWS-20PBA-PKG
39	Encoder Board Mount Screws	*
40	Motor Ground Lug	*

† For part ordering information, contact your Swagelok representative.

* Not available as a field replaceable spare part.

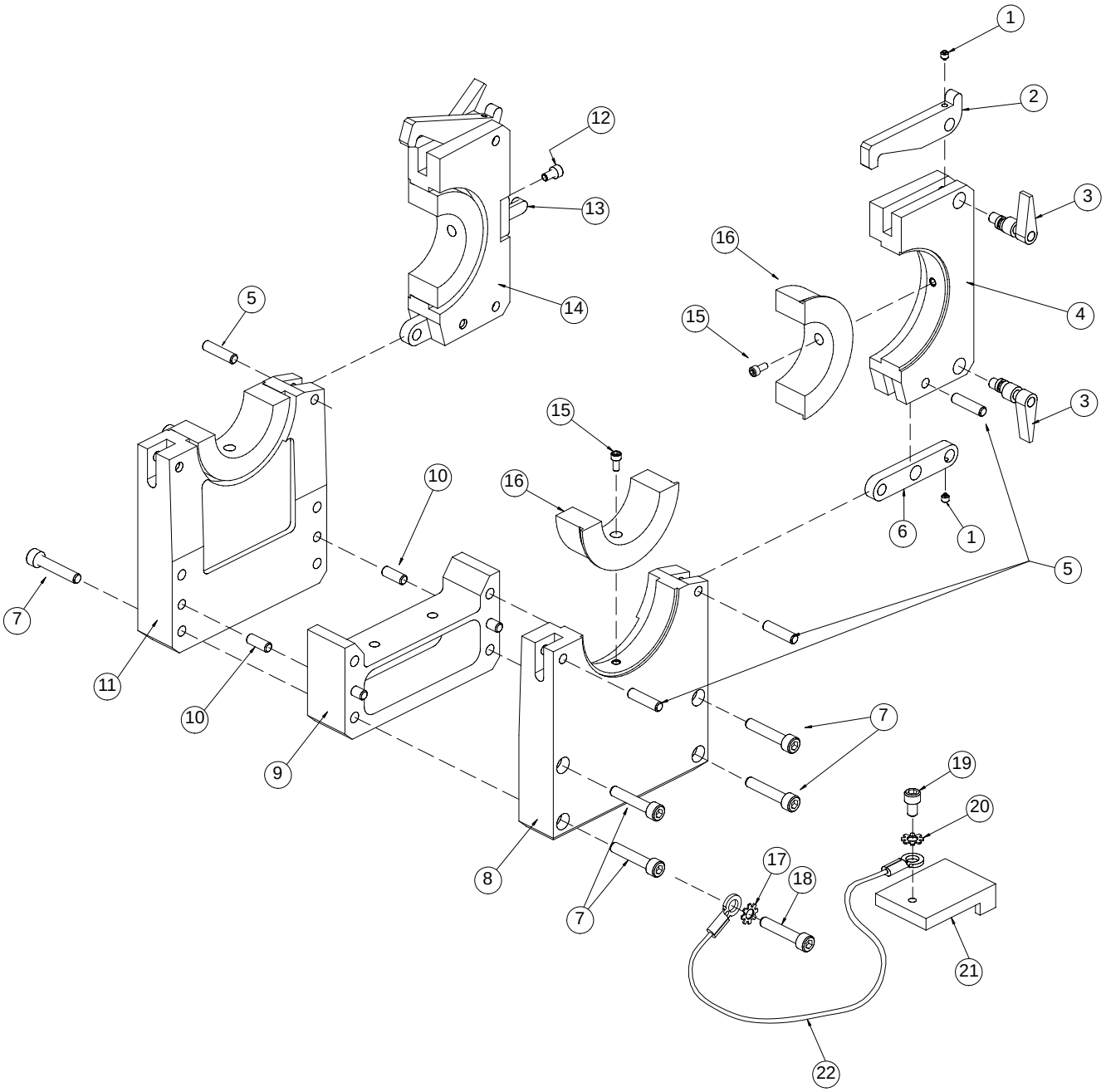


Figure F-12 CWS-20TFB Tube Fixture Block

Table F-12 CWS-20TFB Tube Fixture Block Parts List

Reference No.	Description	Available in Kit No. †
1	Latch Screw	CWS-12306-02 CWS-12307-PKG CWS-20FIX-PKG
2	Latch	CWS-12307-PKG
3	Lever Cam Assembly	CWS-12308-1
4	Top Side Plate (right)	*
5	Hinge and Latch Pins	CWS-20FIX-PKG
6	Hinge	*
7	Side Plate Screws	CWS-20FIX-PKG
8	Bottom Side Plate (right)	*
9	Plenum	CWS-20PLEN
10	Plenum Pins	CWS-20FIX-PKG
11	Bottom Side Plate (left)	*
12	Locking Ring Tab Screws	CWS-12309-PKG CWS-20FIX-PKG
13	Locking Ring Tab	CWS-12309-PKG
14	Top Side Plate (left)	*
15	Collet Insert Screws	CWS-20FIX-PKG, CWS-13112-04
16	Collet Insert	†
17	Lanyard Star Washer	CWS-20CG
18	Lanyard Screw (long, side plate)	CWS-20CG
19	Lanyard Screw (short, centering gage)	CWS-20CG
20	Lanyard Star Washer	CWS-20CG
21	Centering Gage	CWS-20CG
22	Lanyard	CWS-20CG

† For part ordering information, contact your Swagelok representative.
* Not available as a field replaceable spare part.

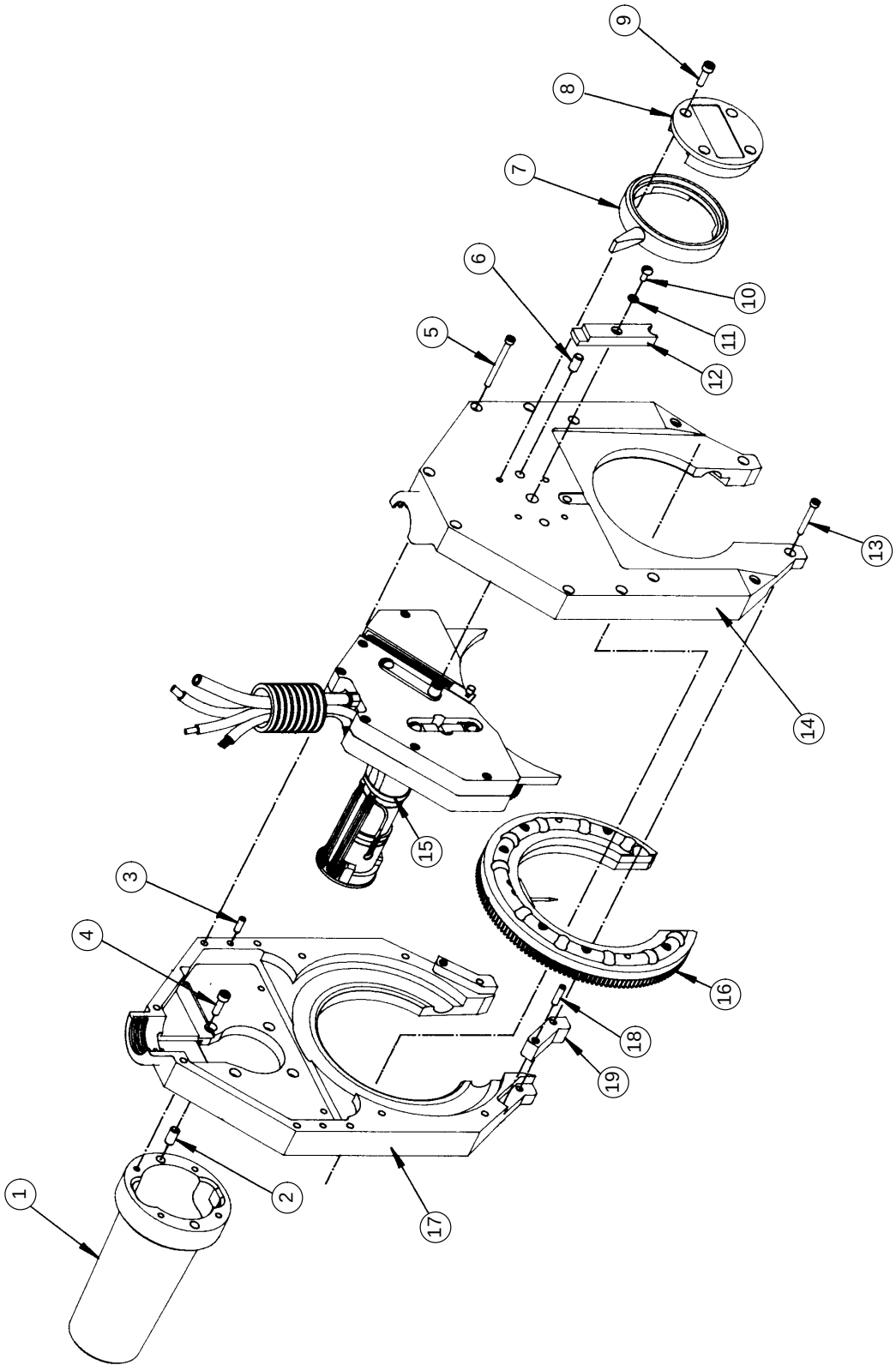


Figure F-14 SWS-20H-B Weld Head

Table F-13 SWS-20H-B Weld Head Parts List

Reference No.	Description	Available in Kit No. †
1	Motor Cover	CWS-11121-PKG
2	Motor Pins	CWS-11121-PKG, CWS-20WHA-PKG
3	Weld Head Housing Pins	CWS-20HP-MTRHOUSE, CWS-20WHA-PKG
4	Motor Cover Screws	CWS-11121-PKG, CWS-20WHA-PKG
5	Weld Head Housing Screws (long)	CWS-20WHA-PKG, SWS-20HBP-MTRHOUSE, SWS-20HBP-LOCHOUSE
6	Locking Ring Plate Pins	CWS-11104-PKG, CWS-20WHA-PKG
7	Locking Ring with Handle	CWS-11106−1
8	Locking Ring Plate	CWS-11104-PKG
9	Locking Ring Plate Screws	CWS-11104-PKG, CWS-20WHA-PKG
10	Work (+) Extension Screw	CWS-11112-PKG, CWS-13101-05
11	Work (+) Extension Washer	CWS-11112-PKG
12	Work (+) Extension	CWS-11112-PKG
13	Weld Head Housing Screws (short)	CWS-20WHA-PKG, SWS-20HBP-MTRHOUSE, SWS-20HBP-LOCHOUSE
14	Weld Head Housing (locking ring side)	SWS-20HBP-LOCHOUSE
15	Motor and Power Block Assembly	*
16	Rotor Assembly	SWS-20HBP-ROTOR
17	Weld Head Housing (motor cover side)	SWS-20HBP-MTRHOUSE
18	Bearing Pad Pins	SWS-20HBP-BEARINGPAD
19	Bearing Pad	SWS-20HBP-BEARINGPAD

† For part ordering information, contact your Swagelok representative.

* Not available as a field replaceable spare part.

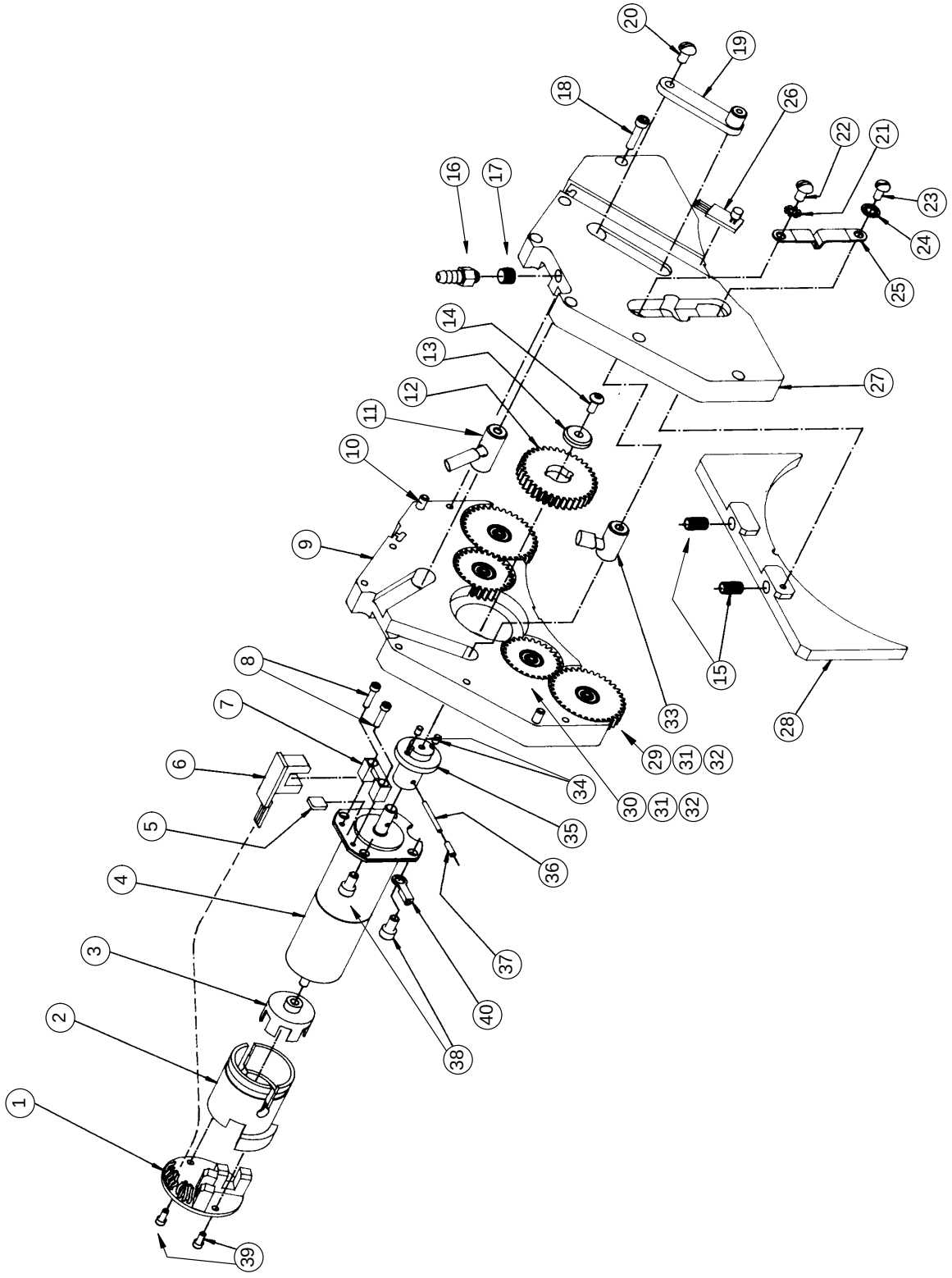


Figure F-15 SWS-20H-B Motor and Power Block Assembly

Table F-14 SWS-20H-B Motor and Power Block Assembly Parts List

Reference No.	Description	Available in Kit No. †
1	Encoder Board Assembly	*
2	Encoder Sleeve	*
3	Encoder Wheel	*
4	Motor	*
5	Spacer	*
6	Home Sensor Assembly	*
7	Sensor Mount	*
8	Sensor Mount Screws	*
9	Power Block Housing (motor side)	CWS-20PBH-PKG, CWS-20PBH-A-PKG
10	Power Block Pins	CWS-20PBH-PKG, CWS-20PBH-A-PKG CWS-20PBA-PKG
11	Work(+) Post	*
12	Drive Gear	CWS-11315-PKG
13	Drive Gear Washer	CWS-11315-PKG
14	Drive Gear Screw	CWS-11315-PKG
15	Brush Springs	CWS-11305-PKG, CWS-11205-02 CWS-20PBA-PKG
16	Gas Bayonet	CWS-20PBH-PKG, CWS-20PBH-A-PKG
17	Thread Insert	CWS-20PBH-PKG, CWS-20PBH-A-PKG
18	Power Block Screws	CWS-20PBH-PKG, CWS-20PBH-A-PKG CWS-20PBA-PKG
19	Work(+) Plate	CWS-11060-PKG
20	Work(+) Plate Screw	CWS-11060-PKG, CWS-20PBA-PKG
21	Power Strap Internal Star Washer	CWS-11117-PKG
22	Power Strap Screw (large)	CWS-11117-PKG, CWS-20PBA-PKG
23	Power Strap Screw (small)	CWS-11117-PKG, CWS-20PBA-PKG
24	Power Strap External Star Washer	CWS-11117-PKG
25	Power Strap	CWS-11117-PKG
26	Safety Interlock Sensor	*
27	Power Block Housing (brush side)	CWS-20PBH-PKG, CWS-20PBH-A-PKG
28	Brush	CWS-11305-PKG
29, 31, 32	Secondary Gear Assy (gear, bearing, gear pin)	CWS-11313-PKG
30, 31, 32	Primary Gear Assy (gear, bearing, gear pin)	CWS-11141-PKG
33	Electrode(−) Post	*
34	Drive Coupler Pins	CWS-11315-PKG
35	Drive Coupler	*
36	Drive Coupler Motor Pin	*
37	Sleeve	*
38	Motor Mounting Screws	CWS-20PBA-PKG
39	Encoder Board Mount Screws	*
40	Motor Ground Lug	*

† For part ordering information, contact your Swagelok representative.

* Not available as a field replaceable spare part.

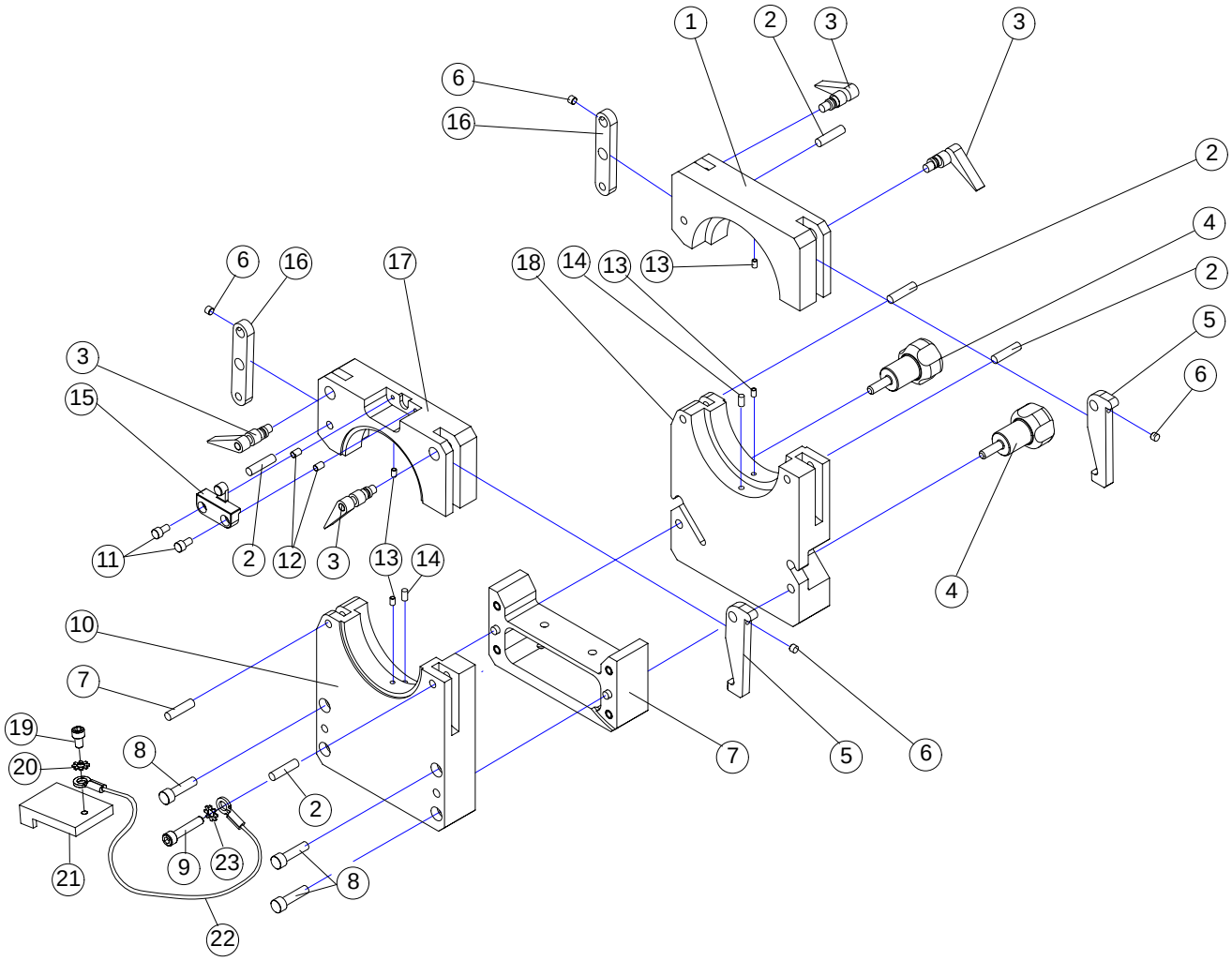


Figure F-16 SWS-20TFB-A Tube Fixture Block

Table F-15 SWS-20TFB-A Tube Fixture Block Parts List

Reference No.	Description	Available in Kit No. †
1	Top Side Plate (right)	SWS-20TSPR-A
2	Hinge and Latch Pin	CWS-20FIX-PKG
3	Lever Cam Assembly	CWS-12308-1
4	Knob	SWS-20FP-KNOB
5	Latch	CWS-12307-PKG
6	Latch and Hinge Screw	CWS-12306-02
7	Plenum	SWS-20BPLEN
8	Side Plate Screws	CWS-20FIX-PKG
9	Lanyard Screw (long, side plate)	SWS-20CG-A
10	Bottom Side Plate (left)	SWS-20TSPL-A
11	Locking Ring Tab Screw	SWS-20FP-LOCKTAB
12	Helicoil	*
13	Insert	*
14	Dowel Pin	*
15	Locking Ring Tab	SWS-20FP-LOCKTAB
16	Hinge	*
17	Top Side Plate (left)	SWS-20TSPL-A
18	Bottom Side Plate (right)	SWS-20TSPR-A
19	Lanyard Screw (short)	SWS-20CG-A
20	Lanyard Star Washer	SWS-20CG-A
21	Centering Gage	SWS-20CG-A
22	Lanyard	SWS-20CG-A
23	Lanyard Star Washer	SWS-20CG-A

† For part ordering information, contact your Swagelok representative.
* Not available as a field replaceable spare part.

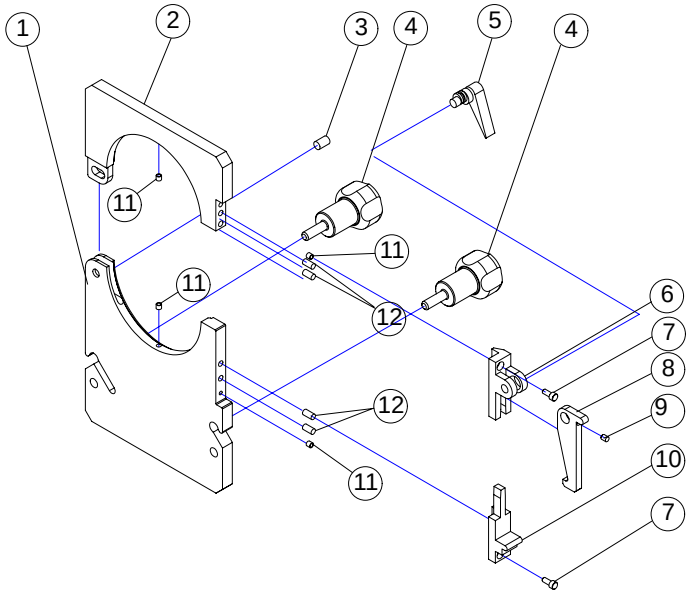


Figure F-17 SWS-20FSP1R Special Purpose Fixture Block

Table F-16 SWS-20FSP1R Special Purpose Fixture Block Parts List

Reference No.	Description	Available in Kit No. †
1	Bottom Side Plate	*
2	Top Side Plate	*
3	Dowel Pin	*
4	Knob	SWS-20FP-KNOB
5	Lever Cam Assembly	CWS-12130-2
6	Latch Holder	SWS-20FP-LATCH1
7	Screw	CWS-13112-04
8	Latch	CWS-12146-PKG
9	Latch Screw	CWS-12132-02
10	Latch Holder	SWS-20FP-LATCH2
11	Helicoil	*
12	Dowel Pin	CWS-20FIX-PKG

† For part ordering information, contact your Swagelok representative.
* Not available as a field replaceable spare part.

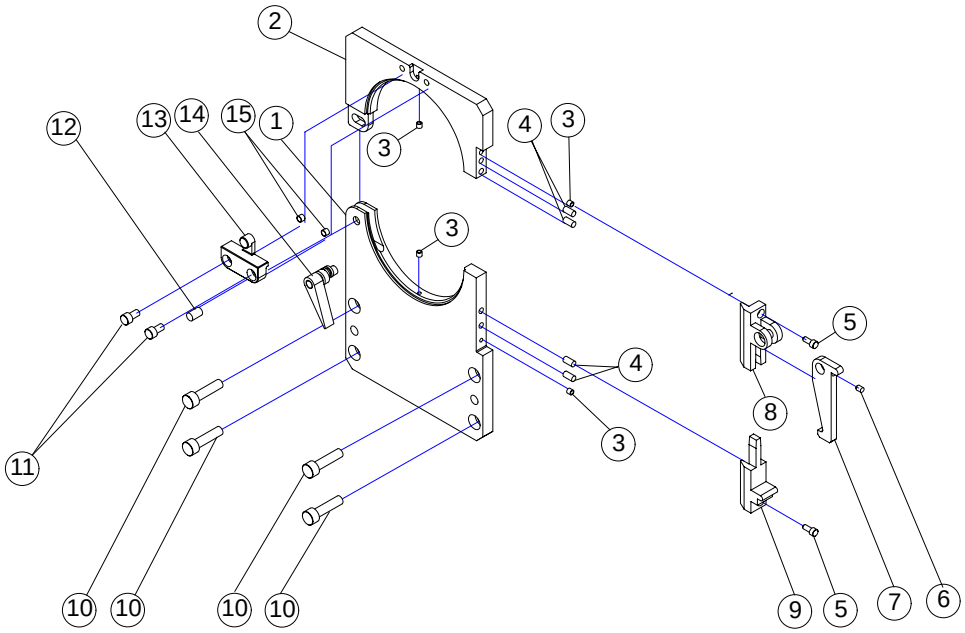


Figure F-18 SWS-20FSP1L Special Purpose Fixture Block

Table F-17 SWS-20FSP1L Special Purpose Fixture Block Parts List

Reference No.	Description	Available in Kit No. †
1	Bottom Side Plate	*
2	Top Side Plate	*
3	Helicoil	*
4	Dowel Pin	CWS-20FIX-PKG
5	Screw	CWS-13112-04
6	Latch Screw	CWS-12132-02
7	Latch	CWS-12146-PKG
8	Latch Holder	SWS-20FP-LATCH3
9	Latch Holder	SWS-20FP-LATCH4
10	Screw	CWS-10FIX-PKG
11	Locking Ring Tab Screw	CWS-13174-10
12	Dowel Pin	*
13	Locking Ring Tab	SWS-20FP-LOCKTAB
14	Lever Cam Assembly	CWS-12308-1
15	Helicoil	*

† For part ordering information, contact your Swagelok representative.
* Not available as a field replaceable spare part.

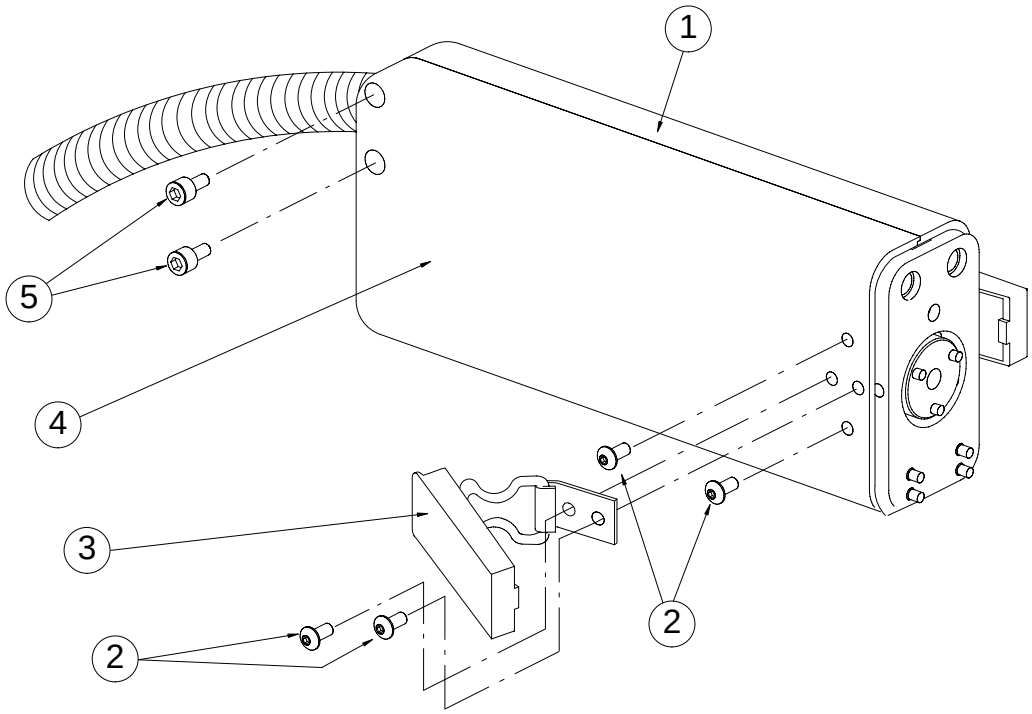


Figure F-19 CWS-M-MTR-A Motor Module

Table F-18 CWS-M-MTR-A Motor Module Parts List

Reference No.	Description	Available in Kit No. †
1	Motor Cover 1	CWS-MP-HOUSING
2	Button Head Screw	CWS-MP-SCREWS CWS-MP-LATCH
3	Latch	CWS-MP-LATCH
4	Motor Cover 1A	CWS-MP-HOUSING
5	Socket Head Cap Screw	CWS-MP-SCREWS

† For part ordering information, contact your Swagelok representative.

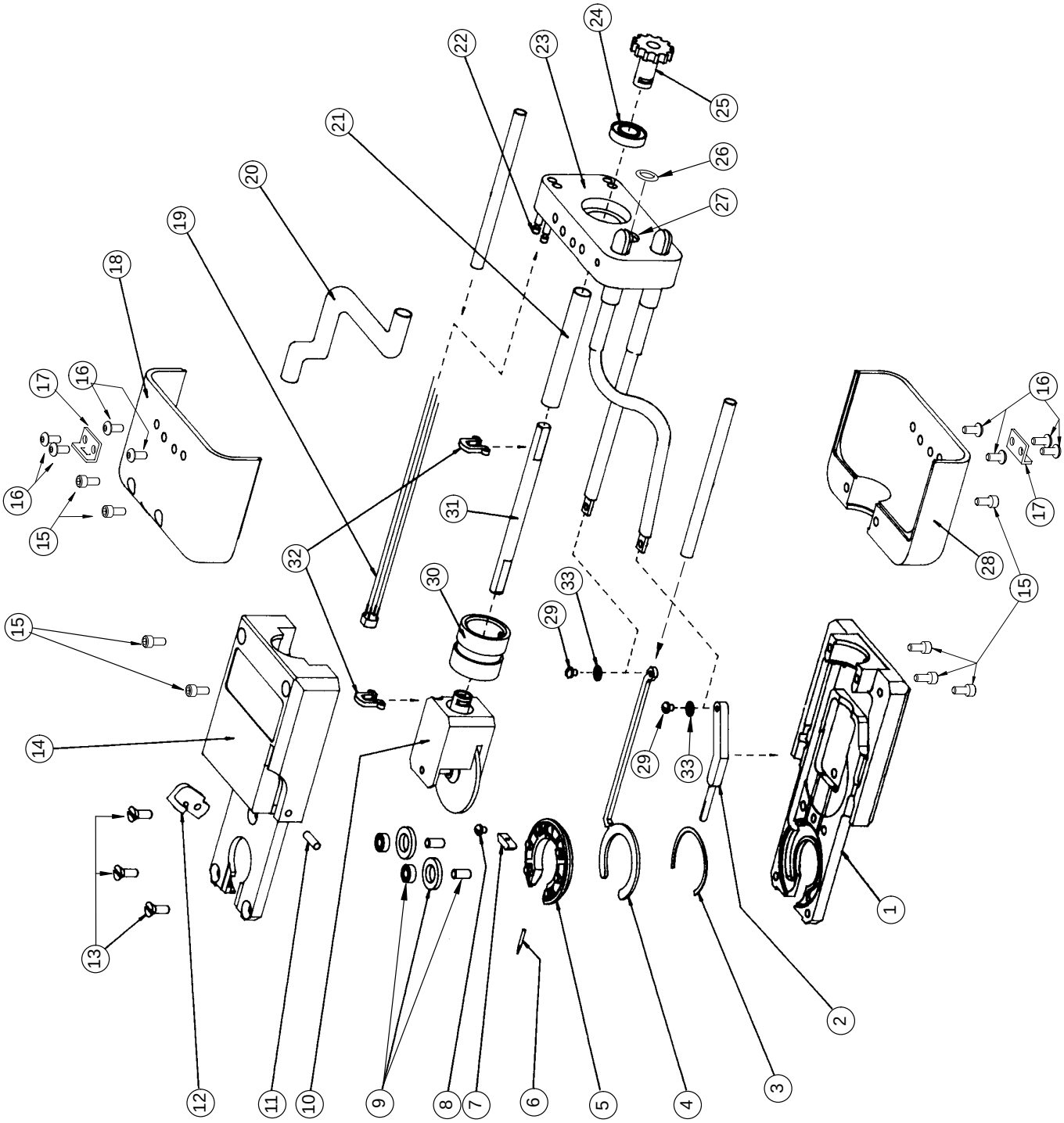


Figure F-20 CWS-4MRH-A Rigid Micro Weld Head

Table F-19 CWS-4MRH-A Rigid Micro Weld Head Parts List

Reference No.	Description	Available in Kit No. †
1	Body Brush Side	CWS-4MHP-BRSHHOUSE CWS-4MHP-BRSHHOUSPL
2	Work(+) Pin Stud	CWS-4MHP-GRDPIN
3	Brush Spring	CWS-4MHP-BRUSH
4	Brush (and insulating cover)	CWS-4MHP-BRUSH
5	Rotor	CWS-4MHP-ROTOR
6	Electrode	CWS-C.040-.405-P, CWS-C.040-.325-P
7	Ceramic Insert	CWS-4MHP-ROTOR, CWS-4MHP-CERAMIC
8	Electrode Screw	CWS-4MHP-ROTOR, CWS-4MHP-CERAMIC
9	Idler Gear Assembly	CWS-4MHP-IDLER
10	Transmission Assembly	CWS-4MHP-TRANS
11	Dowel Pin	CWS-4MHP-LEVER
12	Locking Lever	CWS-4MHP-LEVER
13	Slotted Flat Head Screw	CWS-4MHP-SCREWS, CWS-4MHP-BRSHHOUSE CWS-4MHP-BRSHHOUSPL CWS-4MHP-GEARHOUSE, CWS-13157-10
14	Body Gear Side	CWS-4MHP-GEARHOUSE
15	Socket Head Cap Screw	CWS-4MHP-SCREWS, CWS-4MHP-BRSHHOUSE CWS-4MHP-BRSHHOUSPL CWS-4MHP-GEARHOUSE
16	Button Head Screw	CWS-4MHP-SCREWS
17	Latch Keeper	CWS-MP-LATCH
18	Motor Cover 2	*
19	Safety Interlock Sensor Assembly	*
20	Shielding Gas Tube	*
21	Drive Shaft Insulating Tube	*
22	Safety Interlock Connector Pins	*
23	Interface Plate	*
24	Drive Coupling Gear Bearing	*
25	Drive Coupling Gear	*
26	O-ring	CWS-4MHP-CVA, CWS-4MHP-ORING
27	Check Valve Actuator	CWS-4MHP-CVA
28	Motor Cover 2A	*
29	Slotted Round Head Screw	CWS-4MHP-SCREWS, CWS-4MHP-BRUSH CWS-4MHP-GRDPIN
30	Solid Drive Coupling	*
31	Solid Drive Shaft	*
32	Drive Clip	CWS-4MHP-TRANS, CWS-4MHP-DRVCLP
33	Star Washer	CWS-4MHP-SCREWS, CWS-4MHP-BRUSH CWS-4MHP-GRDPIN

† For part ordering information, contact your Swagelok representative.
* Not available as a field replaceable spare part.

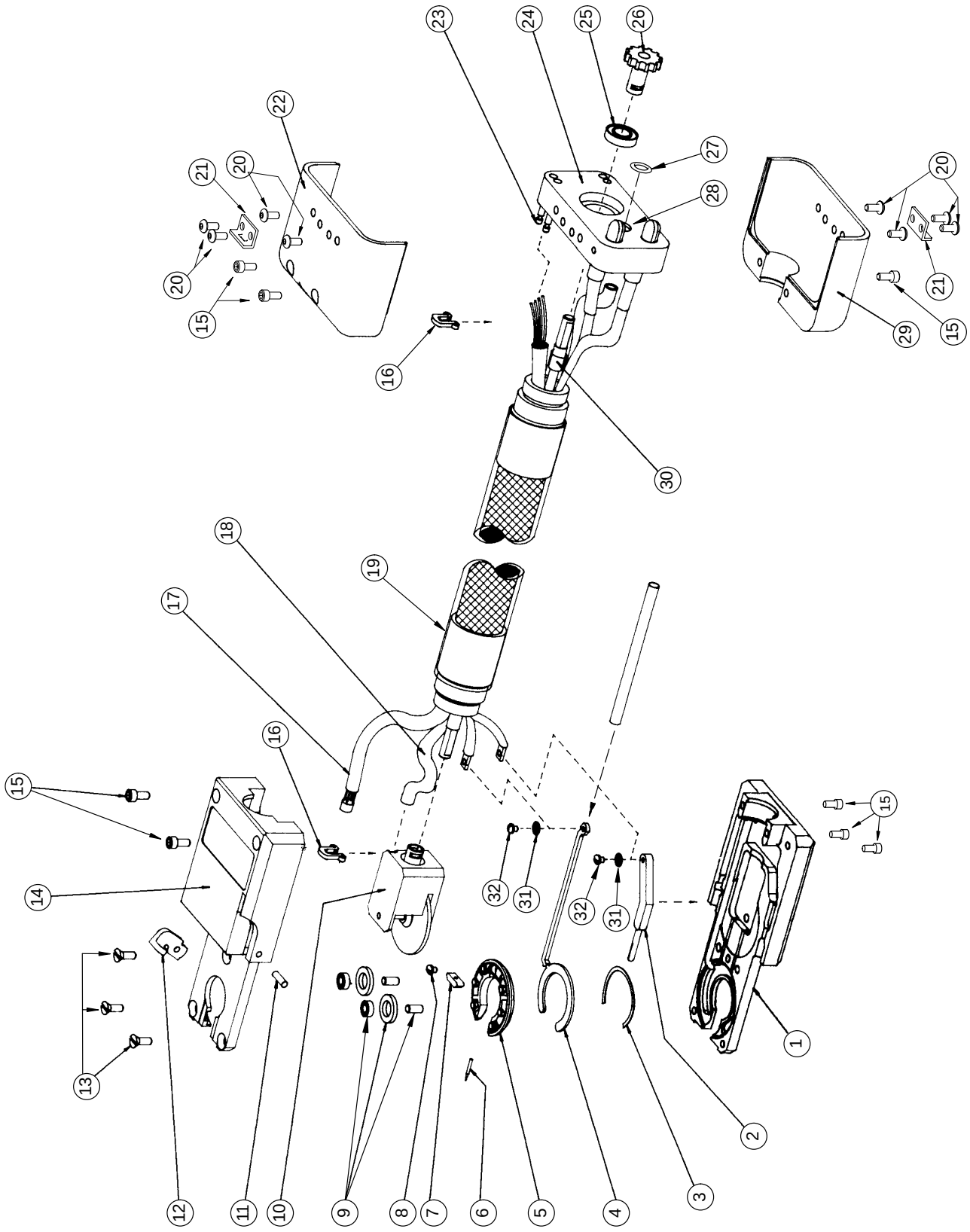


Figure F-21 CWS-4MFH-A Flexible Micro Weld Head

Table F-20 CWS-4MFH-A Flexible Micro Weld Head Parts List

Reference No.	Description	Available in Kit No. †
1	Body Brush Side	CWS-4MHP-BRSHHOUSE CWS-4MHP-BRSHHOUSPL
2	Work(+) Pin Stud	CWS-4MHP-GRDPIN
3	Brush Spring	CWS-4MHP-BRUSH
4	Brush (and insulating cover)	CWS-4MHP-BRUSH
5	Rotor	CWS-4MHP-ROTOR
6	Electrode	CWS-C.040-.405-P, CWS-C.040-.325-P
7	Ceramic Insert	CWS-4MHP-ROTOR, CWS-4MHP-CERAMIC
8	Electrode Screw	CWS-4MHP-ROTOR, CWS-4MHP-CERAMIC
9	Idler Gear Assembly	CWS-4MHP-IDLER
10	Transmission Assembly	CWS-4MHP-TRANS
11	Dowel Pin	CWS-4MHP-LEVER
12	Locking Lever	CWS-4MHP-LEVER
13	Slotted Flat Head Screw	CWS-4MHP-SCREWS, CWS-4MHP-BRSHHOUSE CWS-4MHP-BRSHHOUSPL CWS-4MHP-GEARHOUSE, CWS-13157-10
14	Body Gear Side	CWS-4MHP-GEARHOUSE
15	Socket Head Cap Screw	CWS-4MHP-SCREWS, CWS-4MHP-BRSHHOUSE CWS-4MHP-BRSHHOUSPL CWS-4MHP-GEARHOUSE
16	Drive Clip	CWS-4MHP-TRANS, CWS-4MHP-DRVCLP
17	Safety Interlock Sensor Assembly	*
18	Shielding Gas Tube	*
19	Flexible Drive Coupling Assembly	*
20	Button Head Screw	CWS-4MHP-SCREWS
21	Latch Keeper	CWS-MP-LATCH
22	Motor Cover 2	*
23	Safety Interlock Connector Pins	*
24	Interface Plate	*
25	Drive Coupling Gear Bearing	*
26	Drive Coupling Gear	*
27	O-ring	CWS-4MHP-CVA, CWS-4MHP-ORING
28	Check Valve Actuator	CWS-4MHP-CVA
29	Motor Cover 2A	*
30	Flexible Drive Shaft	*
31	Star Washer	CWS-4MHP-SCREWS, CWS-4MHP-BRUSH CWS-4MHP-GRDPIN
32	Slotted Round Head Screw	CWS-4MHP-SCREWS, CWS-4MHP-BRUSH CWS-4MHP-GRDPIN

† For part ordering information, contact your Swagelok representative.

* Not available as a field replaceable spare part.

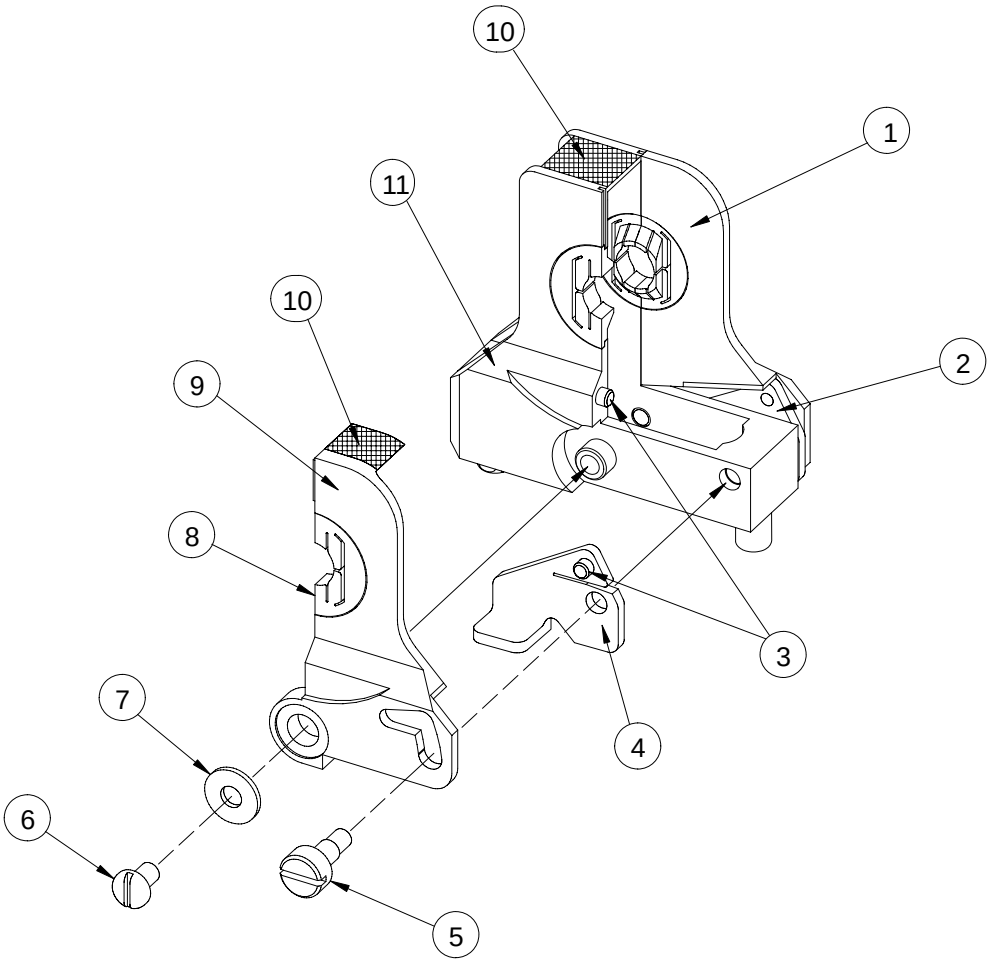


*Figure F-22 CWS-4MFA-** Micro Weld Head Fixture*

*Table F-21 CWS-4MFA-** Micro Weld Head Fixture Parts List*

Reference No.	Description	Available in Kit No. †
1	Side Plate (right)	*
2	Side Plate Cam (right)	CWS-4MFP-LATCH-A
3	Cam Pin	*
4	Side Plate Cam (left)	CWS-4MFP-LATCH-A
5	Shoulder Screw	CWS-4MFP-LATCH-A, CWS-4MFP-SCREWS
6	Binding Screw	CWS-4MFP-LATCH-A, CWS-4MFP-SCREWS
7	Washer	CWS-4MFP-LATCH-A, CWS-4MFP-SCREWS
8	Collet	*
9	Side Plate (left)	*
10	Tape Strips	CWS-4MFP-TAPE
11	Fixture Base	*

** Denotes size in 1/16ths or mm; includes sizes 01, 02, 04, 3 mm, and 6 mm.
† For part ordering information, contact your Swagelok representative.
* Not available as a field replaceable spare part.

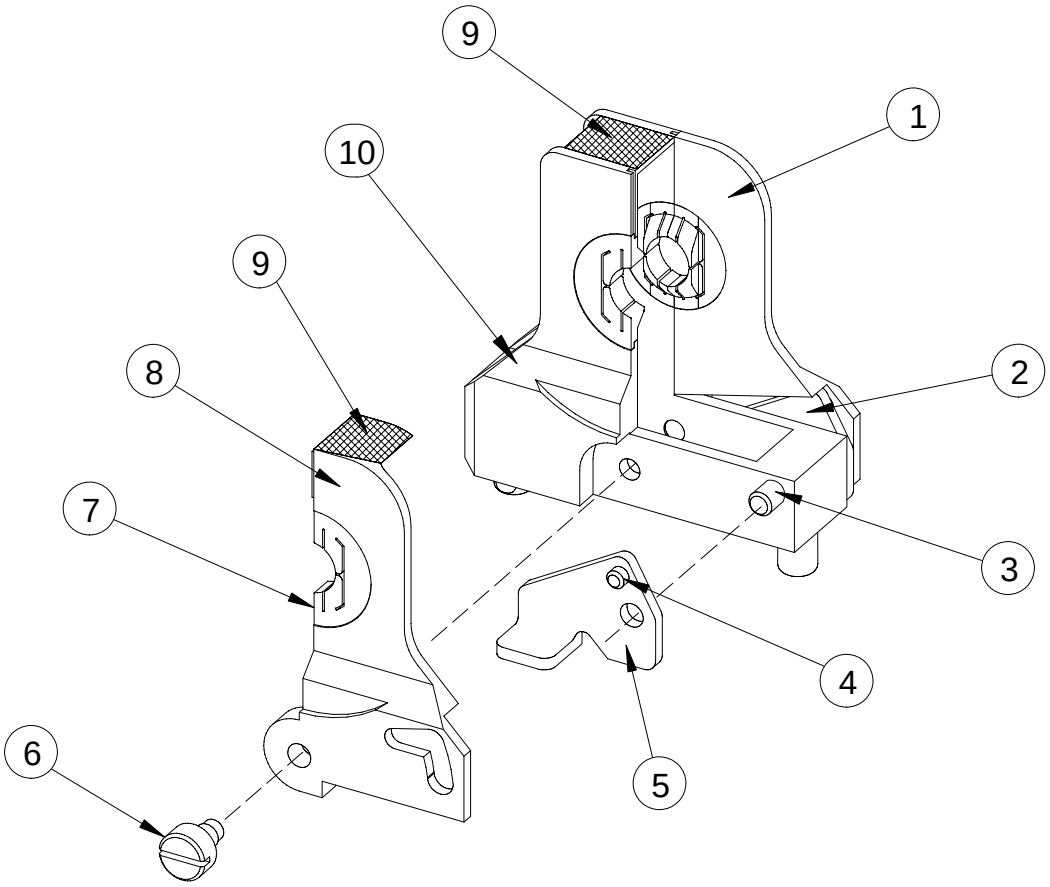


*Figure F-23 CWS-4MF-** Micro Weld Head Fixture*

*Table F-22 CWS-4MF-** Micro Weld Head Fixture Parts List*

Reference No.	Description	Available in Kit No. †
1	Side Plate (right)	*
2	Side Plate Cam (right)	CWS-4MFP-LATCH
3	Dowel Pin (base)	*
4	Cam Pin	*
5	Side Plate Cam (left)	CWS-4MFP-LATCH
6	Shoulder Screw	CWS-4MFP-LATCH, CWS-13198-02
7	Collet	*
8	Side Plate (left)	*
9	Tape Strips	CWS-4MFP-TAPE
10	Fixture Base	*

** Denotes size in 1/16ths or mm; includes sizes 01, 02, 04, 3 mm, and 6 mm.
† For part ordering information, contact your Swagelok representative.
* Not available as a field replaceable spare part.

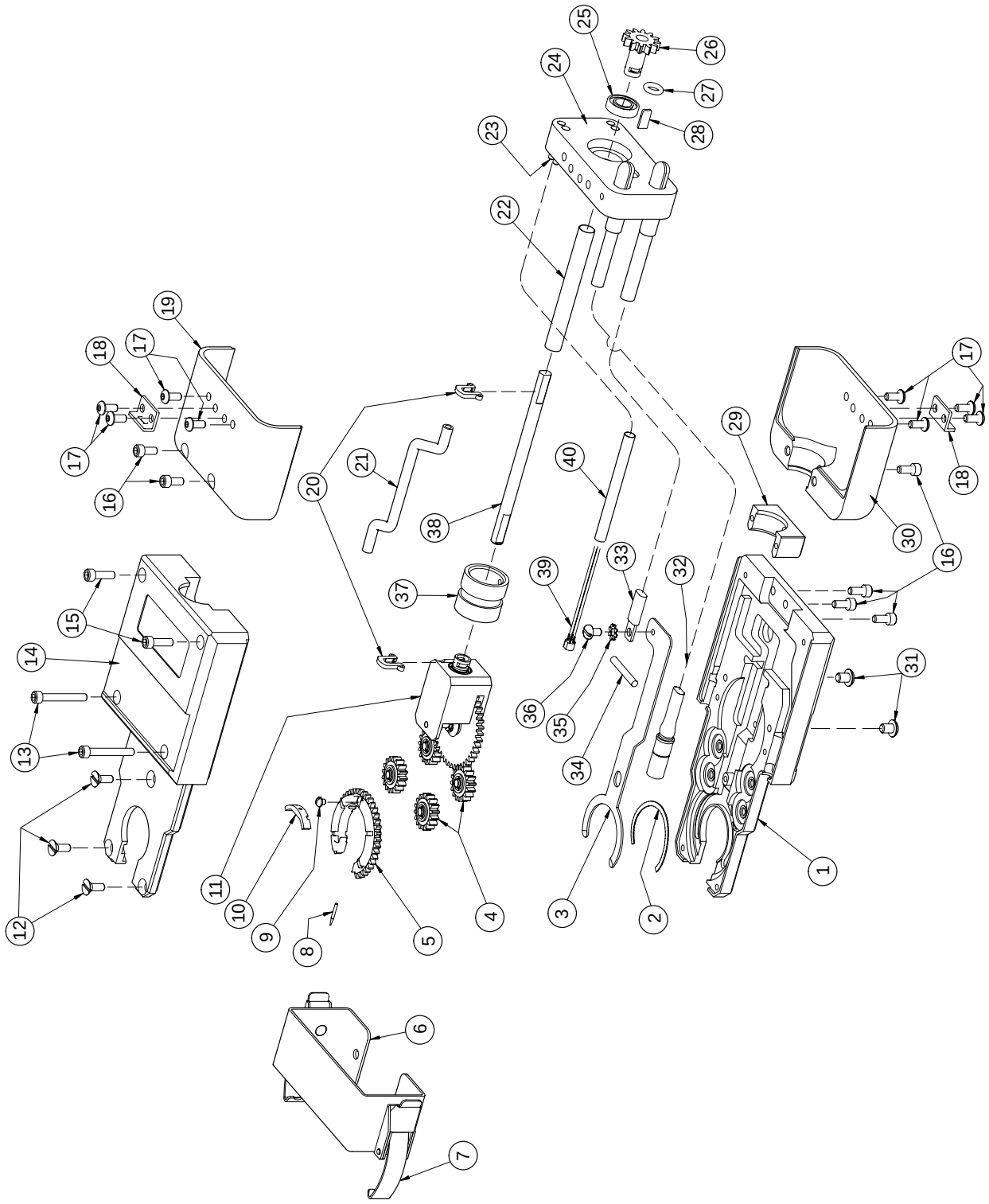


Figure F-24 CWS-8MRH Rigid Micro Weld Head

Table F-23 CWS-8MRH Rigid Micro Weld Head Parts List

Reference No.	Description	Available in Kit No. †
1	Body Brush Side	CWS-8MHP-BRSHHOUSE
2	Power Brush Spring	CWS-8MHP-BRUSH
3	Power Brush/Buss Bar	CWS-8MHP-BRUSH
4	Idler Gear Assembly	CWS-8MHP-IDLER
5	Rotor	CWS-8MHP-ROTOR
6	Latch Bracket	CWS-8MHP-BRACKET
7	Draw Latch	CWS-8MHP-BRACKET, CWS-8MHP-LATCH
8	Electrode	CWS-C.040-.405-P, CWS-C.040-.325-P, CWS-C.040-.281-P, CWS-C.040-.450-P
9	Electrode Screw	CWS-8MHP-ROTOR, CWS-8MHP-CERAMIC, CWS-8MHP-SCREWS
10	Ceramic Insert	CWS-8MHP-ROTOR, CWS-8MHP-CERAMIC
11	Transmission Assembly	CWS-8MHP-TRANS
12	Slotted Flat Head Screw	CWS-8MHP-SCREWS, CWS-8MHP-BRSHHOUSE CWS-8MHP-GEARHOUSE, CWS-13157-10
13	Socket Head Cap Screw	CWS-8MHP-SCREWS, CWS-8MHP-BRSHHOUSE CWS-8MHP-GEARHOUSE
14	Body Gear Side	CWS-8MHP-GEARHOUSE
15	Socket Head Cap Screw	CWS-8MHP-SCREWS, CWS-8MHP-BRSHHOUSE CWS-8MHP-GEARHOUSE
16	Socket Head Cap Screw	CWS-8MHP-SCREWS, CWS-8MHP-BRSHHOUSE CWS-8MHP-GEARHOUSE
17	Button Head Screw	CWS-8MHP-SCREWS, CWS-8MHP-BRSHHOUSE CWS-8MHP-GEARHOUSE
18	Latch Keeper	*
19	Motor Cover 2	*
20	Drive Clip	CWS-8MHP-TRANS, CWS-8MHP-DRVCLP
21	Shielding Gas Tube	*
22	Drive Shaft Insulating Tube	*
23	Safety Interlock Conn. Pins	*
24	Interface Plate	*
25	Drive Coupling Gear Bearing	*
26	Drive Coupling Gear	*
27	O-ring	CWS-8MHP-CVA, CWS-8MHP-ORING
28	Check Valve Actuator	CWS-8MHP-CVA
29	Micro Coupling Collar	CWS-8MHP-BRSHHOUSE
30	Motor Cover 2A	*
31	Button Head Cap Screw	CWS-8MHP-SCREWS, CWS-8MHP-BRSHHOUSE CWS-8MHP-GEARHOUSE, CWS-8MHP-BRACKET
32	Work (+) Cable	*
33	Electrode Cable	*
34	Brush O-Ring Spacer	*
35	Star Washer	CWS-8MHP-SCREWS, CWS-8MHP-BRUSH
36	Slotted Pan Head Screw	CWS-8MHP-SCREWS, CWS-8MHP-BRUSH
37	Solid Drive Coupling	*
38	Solid Drive Shaft	*
39	Safety Interlock Sensor Assy.	*
40	Shrink Tubing	*

† For part ordering information, contact your Swagelok representative.
* Not available as a field replaceable spare part.

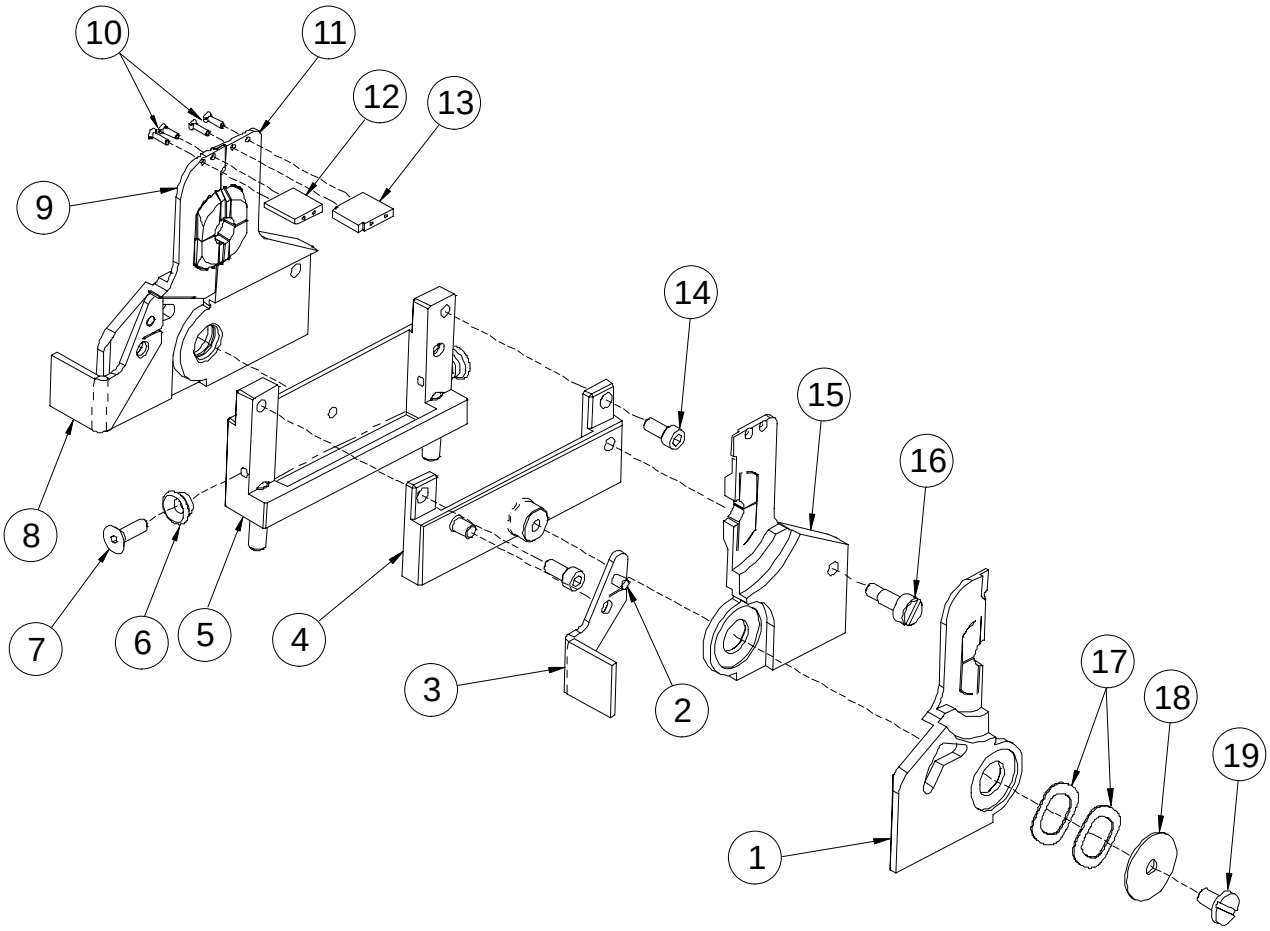


*Figure F-25 SWS-8MFA-** Micro Weld Head Fixture*

*Table F-24 SWS-8MFA-** Micro Weld Head Fixture Parts List*

Reference No.	Description	Available in Kit No. †
1	Moveable Side Plate (right)	SWS-8MFP-MSPR**
2	Cam Pin	SWS-8MFP-LATCH
3	Cam Latch (right)	SWS-8MFP-LATCH
4	Split Base Adjustable Side	SWS−8MFP−BASEPKG−A
5	Split Base Fixed Side	SWS−8MFP−BASEPKG−A
6	Button Keeper	SWS−8MFP−BASEPKG−A, SWS−8MFP−SCREWS
7	Flat Head Screw	SWS−8MFP−BASEPKG−A, SWS−8MFP−SCREWS
8	Cam Latch (LEFT)	SWS−8MFP−LATCH
9	Moveable Side Plate (LEFT)	SWS−8MFP−MSPL**
10	Slotted Flat Head Screw	SWS−8MFP−ARCCVRPKG, SWS−8MFP−SCREWS
11	Fixed Side Plate (RIGHT)	SWS−8MFP−FSPR**
12	Moveable Arc Cover	SWS−8MFP−ARCCVRPKG
13	Fixed Arc Cover	SWS−8MFP−ARCCVRPKG
14	Socket Head Screw	SWS−8MFP−BASEPKG−A, SWS−8MFP−SCREWS
15	Fixed Side Plate (LEFT)	SWS−8MFP−FSPL**
16	Shoulder Screw	SWS−8MFP−BASEPKG−A, SWS−8MFP−SCREWS
17	Wave Spring Washer	SWS−8MFP−BASEPKG−A, SWS−8MFP−SCREWS, SWS−8MFP−MSPR**, SWS−8MFP−MSPL**, SWS−8MFP−FSPR**, SWS−8MFP−FSPL**
18	Flat Washer	SWS−8MFP−BASEPKG−A, SWS−8MFP−SCREWS, SWS−8MFP−MSPR**, SWS−8MFP−MSPL**, SWS−8MFP−FSPR**, SWS−8MFP−FSPL**
19	Binding Screw	SWS−8MFP−SCREWS, SWS−8MFP−MSPR**, SWS−8MFP−MSPL**, SWS−8MFP−FSPR**, SWS−8MFP−FSPL**
20	Tape Strips	SWS−8MFP−TAPE

** Denotes size in 1/16ths or mm; includes sizes 04, 06, 08, 6 mm, 8 mm, 10 mm, and 12 mm.
† For part ordering information, contact your Swagelok representative.

Appendix G
Gas Flow Rate Tables

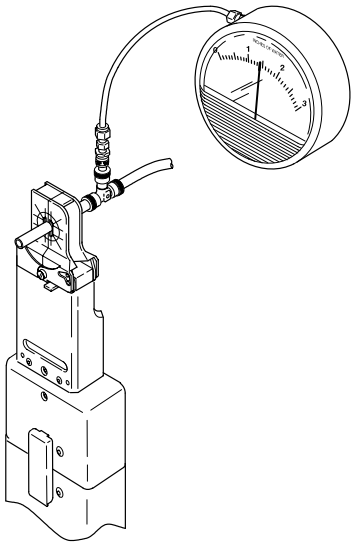


Figure G-1 Pressure Gage

Purge Rate and Pressure Tables

Tube Size	Wall Thickness	*Minimum ID Purge Rate	Pressure	Swagelok Head Purge Rates	Restrictor Size
			13 to 16.8 torr		
1/16 in.	0.015 in.	3 std ft3/hr	7 to 9 iwc	10 to 20 std ft3/hr	n/a
n/a	n/a	1.5 std L/min	175 to 230 mmwc	5 to 10 std L/min	
			17.4 to 22.4 mb		
			9.3 to 16.8 torr		
1/8 in.	0.028 in.	5 std ft3/hr	5 to 9 iwc	10 to 20 std ft3/hr	1/16 in.
3 mm	0,8 mm	2.3 std L/min	130 to 230 mmwc	5 to 10 std L/min	
			12.4 to 22.4 mb		
			5.2 to 6.3 torr		
1/4 in.	0.035 in.	7 std ft3/hr	2.8 to 3.4 iwc	10 to 20 std ft3/hr	1/8 in.
6 mm	1 mm	2.5 std L/min	71 to 86 mmwc	5 to 10 std L/min	3 mm
			7.0 to 8.5 mb		
			2.8 to 4.7 torr		
3/8 in.	0.035 in.	7 std ft3/hr	1.5 to 2.5 iwc	10 to 20 std ft3/hr	1/8 in.
10 mm	1 mm	2.5 std L/min	38 to 64 mmwc	5 to 10 std L/min	3 mm
			3.7 to 6.2 mb		
			1.9 to 2.8 torr		
1/2 in.	0.049 in.	15 std ft3/hr	1.0 to 1.5 iwc	10 to 25 std ft3/hr	1/4 in.
12 mm	1 mm	7 std L/min	25 to 38 mmwc	5 to 12 std L/min	6 mm
			2.5 to 3.7 mb		

Purge Rate and Pressure Tables Continued

Tube Size	Wall Thickness	*Minimum ID Purge Rate	Pressure	Swagelok Head Purge Rates	Restrictor Size
			1 to 2 torr		
3/4 in.	0.065 in.	20 std ft3/hr	0.5 to 1.1 iwc	15 to 30 std ft3/hr	1/4 in.
20 mm	1,5 mm	10 std L/min	13 to 28 mmwc	7 to 14 std L/min	6 mm
			1.2 to 2.7 mb		
			1 to 1.9 torr		
1 in.	0.065 in.	40 std ft3/hr	0.5 to 1.0 iwc	15 to 30 std ft3/hr	1/4 in.
25 mm	1,5 mm	20 std L/min	13 to 25 mmwc	7 to 14 std L/min	6 mm
			1.2 to 2.5 mb		
			1 to 1.3 torr		
1 1/2 in.	0.065 in.	80 std ft3/hr	0.5 to 0.7 iwc	15 to 25 std ft3/hr	1/4 in.
38 mm	1,5 mm	40 std L/min	13 to 18 mmwc	7 to 12 std L/min	6 mm
			1.2 to 1.7 mb		
			0.7 to 1.3 torr		
2 in.	0.065 in.	150 std ft3/hr	0.4 to 0.7 iwc	15 to 25 std ft3/hr	3/8 in.
50 mm	1,5 mm	70 std L/min	13 to 18 mmwc	7 to 12 std L/min	10 mm
			1.0 to 1.7 mb		

These tables for use on butt welds only.

ATW welds and Weld Ring welds typically will require approximately 15 % more purge pressure.

Head purge rates exceed Swagelok recommendations. Be cautious of arc wander.

For best results, use constant head purge between welding cycles.

Pressures must be adjusted for ID encroachment of 0 to +10 % of wall thickness at the bottom of the weld.

*Indicated purge rates are for minimum color line.

ID purge rates shall be adjusted to the desired ID color line.

Restrictor sizes are approximate; purge rate & pressure are critical parameters.

General Suggested Shielding Gas Flow Rates (Argon)

Weld Head Series	std ft^3/h	L/min
5	10 to 15	4.7 to 7.1
10	10 to 20*	4.7 to 9.4
20-A 20−B	10 to 20* 20 to 40*	4.7 to 9.4 9.4 to 18.8
4MH	8 to 10	4 to 4.7
8MH	15 to 20	7.1 to 9.4

* Set the flow to the higher rates when welding at high current levels.

Appendix H
Fixture Block Alignment

Series 5 Fixture Block

The modular design of the Series 5 Fixture Block allows you to assemble the block to meet a variety of welding requirements.

In order to maintain precise alignment of the work pieces in the fixture block, the side plates must be periodically aligned.

This section covers:

- tube-to-tube
- Micro-Fit fitting-to-tube
- Micro-Fit fitting-to-Micro-Fit fitting.

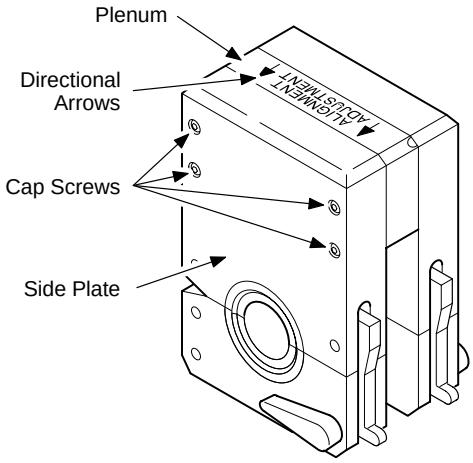


Figure H-1 Loosening the Side Plate

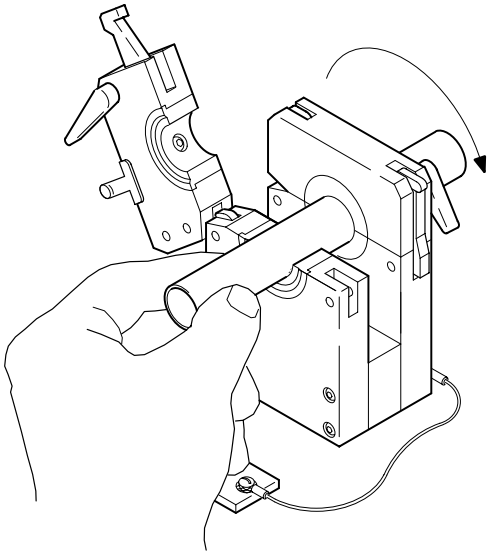


Figure H-2 Placing the Tubing

Tube-to-Tube Fixture Block

To align the fixture block, follow these steps:

1. Turn the fixture block over and locate the directional arrows on the plenum. The arrows point to the appropriate side plate. See Figure H-1.
2. Using the provided 3/32 in. hex wrench, unscrew the four cap screws in the appropriate side plate just enough to loosen it from the plenum. See Figure H-1 to locate the appropriate side plate.
3. Turn the fixture block upright and release both levers and open both sides of the fixture block.
4. Place a straight length of tubing (minimum length 1.50 in. (38,1 mm)) in the collets such that it rests across both side plates.
5. Close and lock the side plate that is not adjustable. See Figure H-2.
6. Lock down the top of the loosened side plate.
7. Tighten the four cap screws in the loosened side plate. Take care to tighten the screws evenly to prevent the side plate from slipping.
8. Open the side plates and remove the tubing.

Micro-Fit Fitting-to-Tube Fixture Block

To align the fixture block, follow these steps:

1. Turn the fixture block over and locate the directional arrows on the plenum. The arrows point to the appropriate side plate. See Figure H-3.

2. Using the provided 3/32 in. hex wrench, unscrew the four cap screws in the appropriate side plate just enough to loosen it from the plenum. See Figure H-3 to locate the appropriate side plate.

3. Turn the fixture block upright and release the lever and open the top of the tube side plate.

4. Choose and install a collet that holds tubing that matches the outside diameter of the Micro-Fit fitting.

5. Unlatch and remove the top of the CWS-5FSP2 Side Plate. See Figure H-4.

6. Using the centering gage, place a straight length of tubing (minimum length 1.50 in. (38,1 mm)) in the tube side plate and lock down the top of the plate.

7. Place the Micro-Fit fitting in the fitting side plate and close and latch the top.

8. Align the Micro-Fit fitting with the tubing. See Figure H-5.

9. While maintaining the fitting-to-tubing alignment, tighten the four cap screws in the adjustable side plate. Take care to tighten the screws evenly to prevent the side plate from slipping.

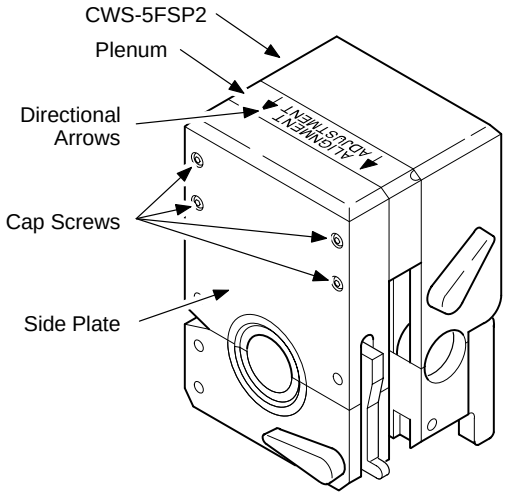


Figure H-3 Loosening the Side Plate

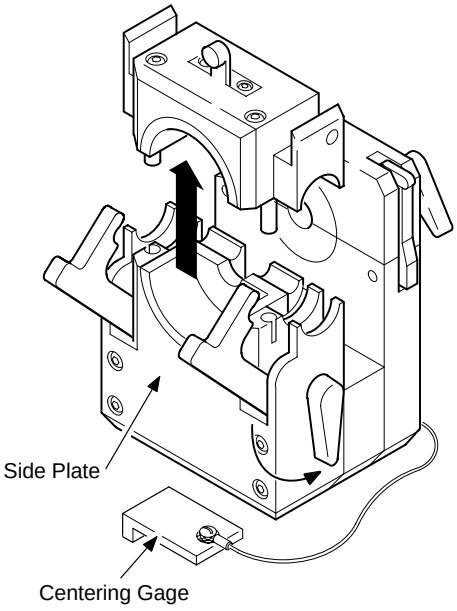


Figure H-4 Removing the Top of the Side Plate

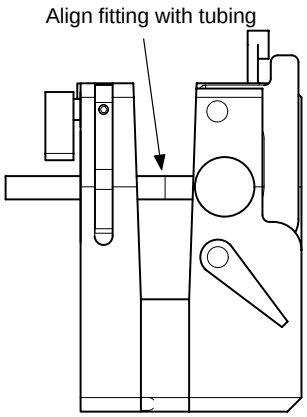


Figure H-5 Aligning the Micro-Fit Fitting With the Tubing

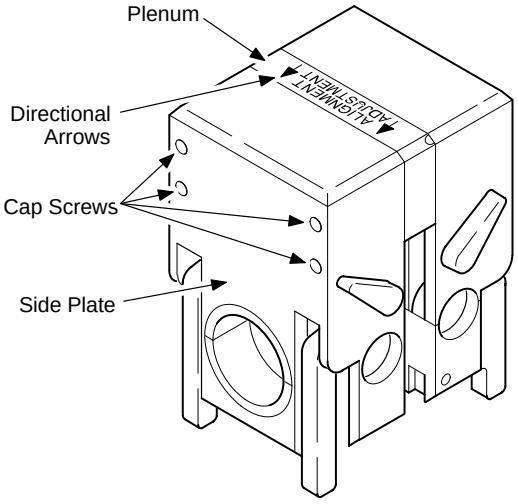


Figure H-6 Loosening the Side Plate

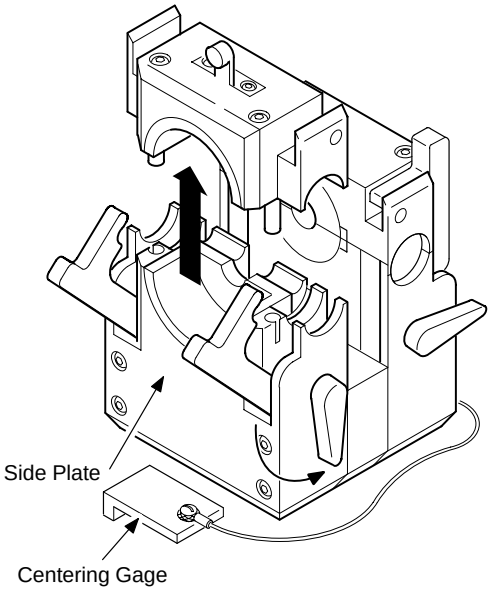


Figure H-7 Removing the Top of the Side Plate

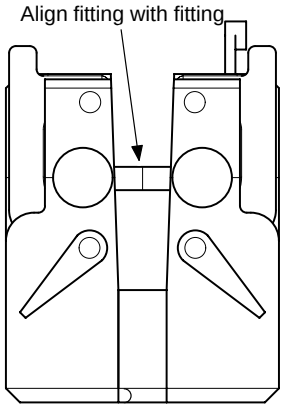


Figure H-8 Aligning the Micro-Fit Fittings

Micro-Fit Fitting to Micro-Fit Fitting Fixture Block

To align the fixture block, follow these steps:

1. Turn the fixture block over and locate the directional arrows on the plenum. The arrows point to the appropriate side plate. See Figure H-6.
2. Using the provided 3/32 in. hex wrench, unscrew the four cap screws in the appropriate side plate just enough to loosen it from the plenum. See Figure H-6 to locate the appropriate side plate.
3. Turn the fixture block upright and remove the tops of the CWS-5FSP2 Side Plates. See Figure H-7.
4. Using the centering gage, place one Micro-Fit fitting in one of the side plates.
5. Reinstall that side plate top.
6. Insert the second Micro-Fit fitting into the other side plate and close its top.
7. Align the two Micro-Fit fittings by adjusting the side plate that is loose. See Figure H-8.
8. While maintaining the fitting-to-fitting alignment, tighten the four cap screws in the adjustable side plate. Take care to tighten the screws evenly to prevent the side plate from slipping.

Series 20H-B Fixture Block

The modular design of the Series 20 Fixture Block allows you to assemble the block to meet a variety of welding requirements.

To align tubing in the Series 20H-B Fixture Block follow these steps:

1. Loosen the Alignment Knobs. See Figure H-9.
2. Align the tubing with the fitting. See Figure H-10.
3. Tighten the Alignment Knobs.

The modular design of the Series 20 Fixture Block allows you to assemble the block to meet a variety of welding requirements.

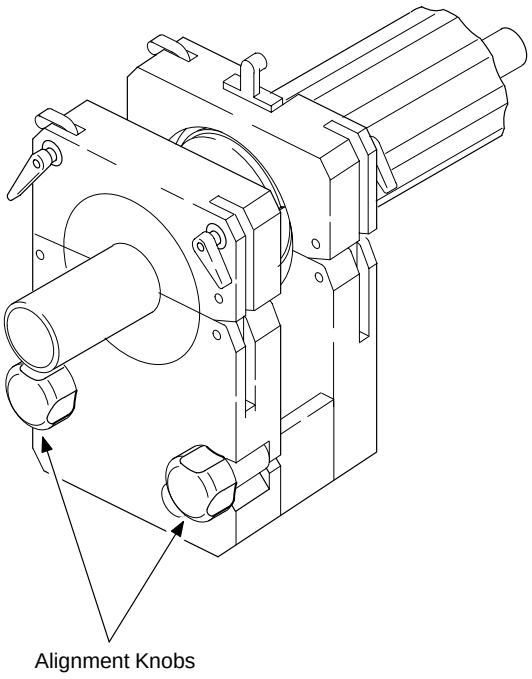


Figure H-9 Aligning the Micro-Fit Fitting with the Tubing

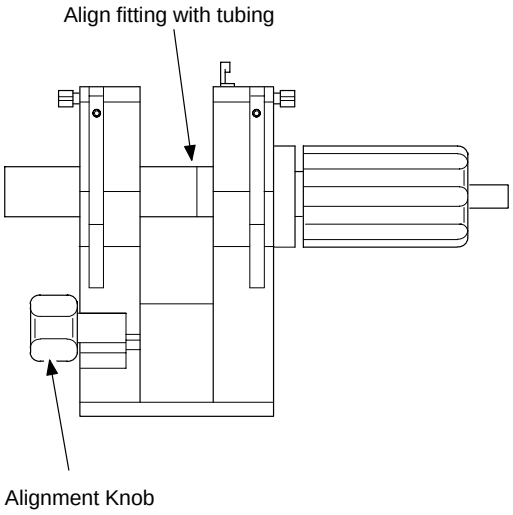


Figure H-10 Aligning the Tubing in the Series 20 Fixture Block

Series 8 Micro Weld Head Fixture

To align tubing in the Series 8 Micro Weld Head Fixture follow these steps:

1. Using the micro fixture tool, place the latch in the open position then open the fixture. See Figure H-11 (A).
2. Loosen the two alignment screws. See Figure H-11 (A).
3. Insert the tubing. See Figure H-11 (B).
4. Close the fixture and latch then align the tubing. See Figure H-11 (C).
5. Tighten the two alignment screws.
   See Figure H-11 (C).

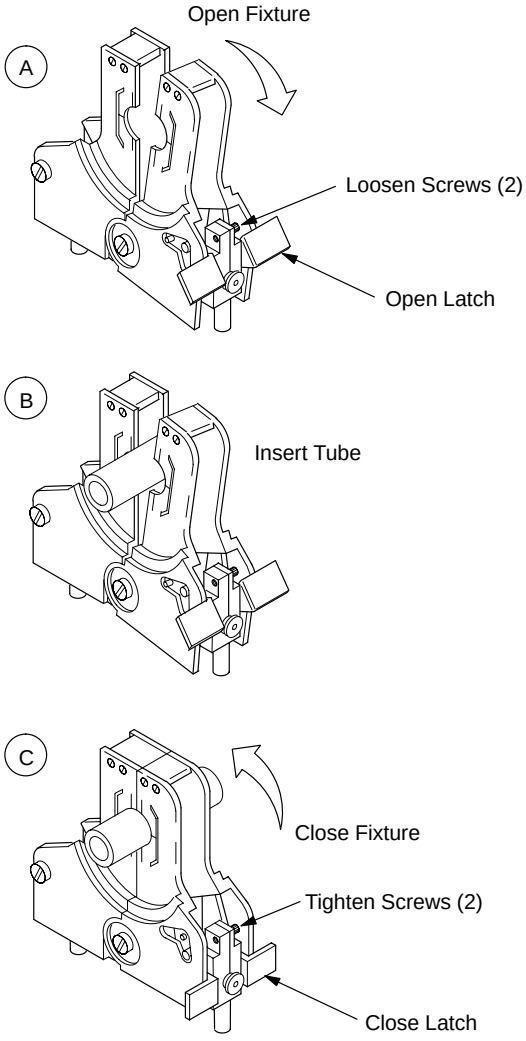


Figure H-11 Aligning the Tubing in the Series 8 Micro Weld Head Fixture

Appendix I
Weld Procedure Guidelines

The table in this appendix lists weld procedure guidelines developed at the factory for your use. These guidelines are **FOR REFERENCE ONLY**. The guidelines show suggested weld parameter settings for various material types and sizes. Modifications of these guidelines may be necessary to achieve the desired weld results.

The weld procedure guideline table shows suggested parameter settings based on the following:

- SWS weld head used
- weld joint type
- material type
- outside diameter and wall thickness of the weld joint

The column labeled “Average Current” lists a calculated value based on certain weld parameters. This value should approximate the value shown on the **Average Current** display during the weld cycle. Because it is a calculated value, some variation may be seen based on the welding conditions.

These guidelines were developed using the same techniques outlined in Section 5, *Weld Parameter Adjustment*. If you need assistance developing additional guidelines, please contact your Swagelok representative.

Table notes

- All 316L material entries refer to type 316L stainless steel.
- All 6LV material entries refer to type 316LV stainless steel.
- TB-TB indicates a tube-to-tube weld joint.
- ATW-TB indicates an ATW fitting-to-tube joint.
- JTB-JTB indicates a Japanese butt end (fractional outside diameter and metric wall thickness) tube-to-tube weld joint.
- MTB-MTB indicates a metric tube-to-tube weld joint.
- MATW-MTB indicates an metric ATW fitting-to-tube joint.
- All outside diameter and wall thickness measurements are in inches if the chart is labeled “English” and in millimeters if the chart is labeled “Metric” unless otherwise noted.

WELD PROCEDURE GUIDELINES - English (For Reference Only)

Weld Head	Joint Type	Material	No. of Passes	OD (in.)	Wall Thickness (in.)	Arc Gap (in.)	Gage Setting (in.)	Travel Speed (in./min)	Impulse	Maintenance	Impulse Rate	Impulse Width	Arc Start	Duration	Prepurge	Weld Time	Downslope	Postpurge	Rotor Speed	Average Current	Shielding (std ft^3/h)	ID Purge (std ft^3/h)
CWS-4MRH-A	TB-TB	316L	Multiple	0.062	0.020	0.020	0.364	4.7	22.0	6.0	10	25	20	0.3	10	5	3	30	99	10.0	8-10	*
				0.125	0.028	0.030	0.405	6.8	30.8	8.0	10	25	20	0.3	10	7	4	30	71	13.7	8-10	1-5
				0.250	0.035	0.035	0.473	7.2	38.5	10.0	10	25	20	0.3	10	13	7	30	38	17.1	8-10	1-5
			Single	0.250	0.035	0.030	0.468	5.1	38.5	10.0	10	24	35	0.8	10	12	4	30	27	16.8	8-10	1-5
	JTB-JTB	6LV	Multiple	0.250	1 mm	0.030	0.468	7.0	43.5	11.0	10	26	20	0.3	10	13	7	30	37	19.5	8-10	1-5
			Single	0.250	1 mm	0.030	0.468	7.0	45.5	11.0	10	28	35	0.8	10	9	3	30	37	20.7	8-10	1-5

* See table on page G-1.

WELD PROCEDURE GUIDELINES - Metric (For Reference Only)

Weld Head	Joint Type	Material	No. of Passes	OD (mm)	Wall Thickness(mm)	Arc Gap(mm)	Gage Setting(mm)	Travel Speed (mm/sec)	Impulse	Maintenance	Impulse	Impulse Width	Arc Start	Duration	Prepurge	Weld Time	Downslope	Postpurge	Rotor Speed	Average Current	Shielding (L/min)	ID Purge (L/min)
CWS-4MRH-A	TB-TB	316L	Multiple	3 mm	0.8	0.640	10.08	3.4	31.0	7.8	12	32	20	0.3	10	6	3	30	90	15.2	3.8-4.7	1-2.4
				6 mm	1.0	0.760	11.70	2.1	43.3	13.0	10	25	20	0.3	10	18	8	30	28	20.6	3.8-4.7	1-2.4
			Single	6 mm	1.0	0.760	11.70	2.1	43.3	13.0	10	23	35	0.8	10	12	4	30	28	20.0	3.8-4.7	1-2.4

Notes:

1. It is suggested that a continuous shielding gas flow be used to extend the life of the micro weld head.
2. On 1/4 in., 3 mm, and 6 mm OD tubing, a restrictor with pressure gage was used.
   Purge gas pressure was set to 2 in. to 4 in. of water for 1/4 in. and 6 mm; 6 in. to 8 in. of water for 3 mm.

WELD PROCEDURE GUIDELINES - English (For Reference Only)

Weld Head	Joint Type	Material	No. of Passes	OD (in.)	Wall Thickness (in.)	Arc Gap (in.)	Gage Setting (in.)	Travel Speed (in./min)	Impulse	Maintenance	Impulse Rate	Impulse Width	Arc Start	Duration	Prepurge	Weld Time	Downslope	Postpurge	Rotor Speed	Average Current	Shielding (std ft^3/h)	ID Purge (std ft^3/h)
CWS-8MRH	TB-TB	316L	Multiple	0.250	0.035	0.035	0.566	6.9	38.5	10.0	10	25	20	0.3	10	14	7	30	36	17.1	15	4-7
				0.375	0.035	0.035	0.629	7.1	38.5	10.0	10	25	20	0.3	10	20	10	30	25	17.1	15	4-7
			Single	0.250	0.035	0.035	0.566	5.1	38.5	10.0	5	33	35	0.8	10	12	4	30	27	19.4	15	4-7
				0.375	0.035	0.035	0.629	5.1	38.5	10.0	5	30	35	0.8	10	19	4	30	18	18.6	15	4-7
				0.500	0.049	0.035	0.691	5.0	58.8	18.0	4	38	50	0.8	10	23	5	30	13	32.3	15-20	4-7
	ATW-TB	316L	Multiple	0.250	0.035	0.035	0.585	6.1	48.0	12.0	10	24	21	0.3	10	16	8	30	32	20.6	15-20	4-7
				0.375	0.035	0.035	0.648	6.3	48.0	12.0	8	32	21	0.3	10	24	12	30	22	23.5	15-20	4-7
			Single	0.250	0.035	0.035	0.585	4.4	48.0	12.0	6	28	35	0.8	10	14	4	30	23	22.1	15-20	4-7
				0.375	0.035	0.035	0.648	4.6	48.0	12.0	8	34	35	0.8	10	20	6	30	16	24.2	15-20	4-7
	JTB-JTB	316L	Multiple	0.250	1 mm	0.030	0.561	6.9	43.5	11.0	10	34	21	0.3	10	14	7	30	36	22.1	12	4-7
				0.375	1 mm	0.035	0.629	6.3	43.5	11.0	8	40	22	0.3	10	23	11	30	22	24.0	12	4-7
			Single	0.250	1 mm	0.030	0.561	6.9	45.5	11.0	10	34	35	0.8	10	10	3	30	36	22.7	12	4-7
				0.375	1 mm	0.035	0.629	6.3	45.5	11.0	8	39	35	0.8	10	16	4	30	22	24.5	12	4-7

Notes:

1. The maximum suggested weld rate on 1/2 in. x 0.049 in. components is 12 welds per hour. This rate can be increased to 15 welds per hour on smaller diameter parts.
2. It is suggested that a continuous shielding gas flow be used to extend the life of the micro weld head.

WELD PROCEDURE GUIDELINES - Metric (For Reference Only)

Weld Head	Joint Type	Material	No. of Passes	OD (mm)	Wall Thickness (mm)	Arc Gap (mm)	Gage Setting (mm)	Travel Speed (mm/sec)	Impulse	Maintenance	Impulse Rate	Impulse Width	Arc Start	Duration	Prepurge	Weld Time	Downslope	Postpurge	Rotor Speed	Average Current	Shielding (L/min)	ID Purge (L/min)
CWS-8MRH	MTB-MTB	316L	Multiple	6	1.0	0.76	14.08	2.1	43.3	14.0	8	26	20	0.3	10	18	8	30	28	21.6	7.1	1.9-3.3
				8	1.0	0.76	15.08	2.1	43.3	14.0	8	28	20	0.3	10	23	11	30	21	22.2	7.1	1.9-3.3
				10	1.0	0.89	16.21	2.2	43.3	13.0	8	38	20	0.3	10	30	15	30	17	24.5	7.1	1.9-3.3
			Single	6	1.0	0.76	14.08	2.1	43.3	13.0	8	29	35	0.8	10	12	4	30	28	21.8	7.1	1.9-3.3
				8	1.0	0.76	15.08	2.1	43.3	14.0	8	30	35	0.8	10	14	4	30	21	22.8	7.1	1.9-3.3
				10	1.0	0.89	16.21	2.2	43.3	14.0	8	40	35	0.8	10	19	5	30	17	25.7	7.1	1.9-3.3
				12	1.0	0.89	17.21	2.1	43.3	16.0	8	42	35	0.8	10	22	6	30	14	26.9	7.1-9.4	1.9-3.3
	MATW-MTB	316L	Multiple	6	1.0	0.76	14.58	2.6	54.4	16.2	10	20	32	0.5	10	15	7	30	34	23.8	7.1	1.9-3.3
				8	1.0	0.76	15.58	2.6	54.4	16.2	8	21	32	0.5	10	20	9	30	26	24.2	7.1	1.9-3.3
				10	1.0	0.89	16.71	1.9	54.4	16.2	8	17	32	0.5	10	33	16	30	15	22.7	7.1	1.9-3.3
			Single	6	1.0	0.76	14.58	2.6	54.4	16.2	10	24	35	0.8	10	10	3	30	34	25.4	7.1	1.9-3.3
				8	1.0	0.76	15.58	2.6	54.4	16.2	8	24	35	0.8	10	13	4	30	26	25.4	7.1	1.9-3.3
				10	1.0	0.89	16.71	1.9	54.4	16.2	8	24	35	0.8	10	18	6	30	15	25.4	7.1	1.9-3.3

Notes:

1. The maximum suggested weld rate on 12 mm x 1.0 mm components is 12 welds per hour. This rate can be increased to 15 welds per hour on smaller diameter parts.
2. It is suggested that a continuous shielding gas flow be used to extend the life of the micro weld head.

WELD PROCEDURE GUIDELINES - English (For Reference Only)

Weld Head	Joint Type	Material	No. of Passes	OD (in.)	Wall Thickness (in.)	Arc Gap (in.)	Gage Setting (in.)	Travel Speed (in./min)	Impulse	Maintenance	Impulse Rate	Impulse Width	Arc Start	Duration	Prepurge	Weld Time	Downslope	Postpurge	Rotor Speed	Average Current	Shielding (std ft^3/h)	ID Purge (std ft^3/h)
CWS-5H-B	TB-TB	316L	Multiple	0.125	0.028	0.030	0.715	4.7	21.5	5.6	25	17	20	0.3	10	10	5	30	99	8.6	12	1-4
				0.250	0.035	0.030	0.777	7.0	38.5	10.0	10	22	20	0.3	10	13	7	30	77	17.0	12	4-7
				0.375	0.035	0.035	0.845	7.0	38.5	10.0	10	31	40	0.3	10	20	10	30	50	19.0	12	5-10
				0.500	0.035	0.035	0.907	7.0	42.5	10.0	10	28	20	0.3	10	27	14	30	37	19.1	12	5-10
				0.500	0.049	0.035	0.907	7.0	58.8	18.0	10	35	32	0.5	10	27	14	30	37	32.0	12	5-10
CWS-10H-A	TB-TB	316L	Multiple	0.250	0.035	0.035	1.157	7.0	38.5	10.0	10	25	20	0.3	20	13	7	30	77	17.0	12-15	4-7
				0.375	0.035	0.035	1.219	7.0	40.5	10.0	10	29	20	0.3	20	20	10	30	50	19.0	12-15	5-10
				0.500	0.035	0.035	1.282	7.0	42.0	10.0	10	34	20	0.3	20	27	14	30	37	20.9	12-15	5-10
				0.500	0.049	0.035	1.282	7.0	58.8	18.0	10	35	32	0.5	20	27	14	30	37	32.0	12-15	5-10
			Single	0.750	0.049	0.045	1.417	5.5	58.8	18.0	6	35	32	0.5	20	26	13	30	19	32.0	12-15	5-10
				1.000	0.065	0.045	1.542	5.0	78.0	23.0	6	35	41	0.5	20	38	19	30	13	41.0	15	7-15
				1.000	0.083	0.045	1.542	5.0	99.6	30.0	6	39	54	0.5	20	38	19	30	13	57.1	15-17	7-15
CWS-20H-A SWS-20H-B	TB-TB	316L	Multiple	0.500	0.035	0.040	1.849	7.0	38.5	10.0	10	27	20	0.3	30	28	14	30	74	18.0	12-15	5-10
				0.500	0.049	0.040	1.849	6.0	58.8	18.0	10	25	40	0.5	30	31	16	30	65	28.0	12-15	5-10
			Single	0.750	0.049	0.045	1.980	5.0	58.8	18.0	6	43	32	0.5	30	28	14	30	36	35.0	12-15	5-10
				1.000	0.065	0.045	2.105	5.0	78.0	23.0	6	35	42	0.5	30	38	19	30	26	42.0	12-15	7-15
				1.000	0.083	0.045	2.105	4.0	99.6	30.0	6	35	54	0.5	30	47	24	30	21	54.0	15	7-15
				1.250	0.065	0.045	2.230	5.0	78.0	23.0	4	35	42	0.5	30	47	24	30	21	42.0	15	7-15
				1.250	0.083	0.045	2.230	4.0	99.6	30.0	4	35	54	0.5	30	59	30	30	17	54.0	15	7-15
				1.500	0.065	0.045	2.355	5.0	78.0	23.0	4	43	42	0.5	30	57	29	30	18	47.0	15	7-15
				1.500	0.083	0.045	2.355	4.0	99.6	30.0	4	50	54	0.5	30	71	36	30	14	64.8	15	7-15
				1.750	0.065	0.045	2.480	4.0	78.0	23.0	4	35	42	0.5	30	82	41	30	12	42.0	15	10-20
				2.000	0.065	0.045	2.605	5.0	78.0	23.0	4	39	42	0.5	30	75	38	30	13	42.0	15	10-20
				2.000	0.083	0.045	2.605	4.0	99.6	30.0	4	40	54	0.5	30	94	47	30	11	57.8	15-17	10-20
				2.000	0.109	0.045	2.605	4.0	99.9	57.0	4	50	78	1.0	30	94	47	30	11	78.5	15-20	10-20

Index

A

B

C

D

E

F

G

H

I

J

M

O

P

Q

R

S

T

U

W

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